Atmospheric Dynamics III

Determine properties of the synoptic-scale mid-latitude system indicated.

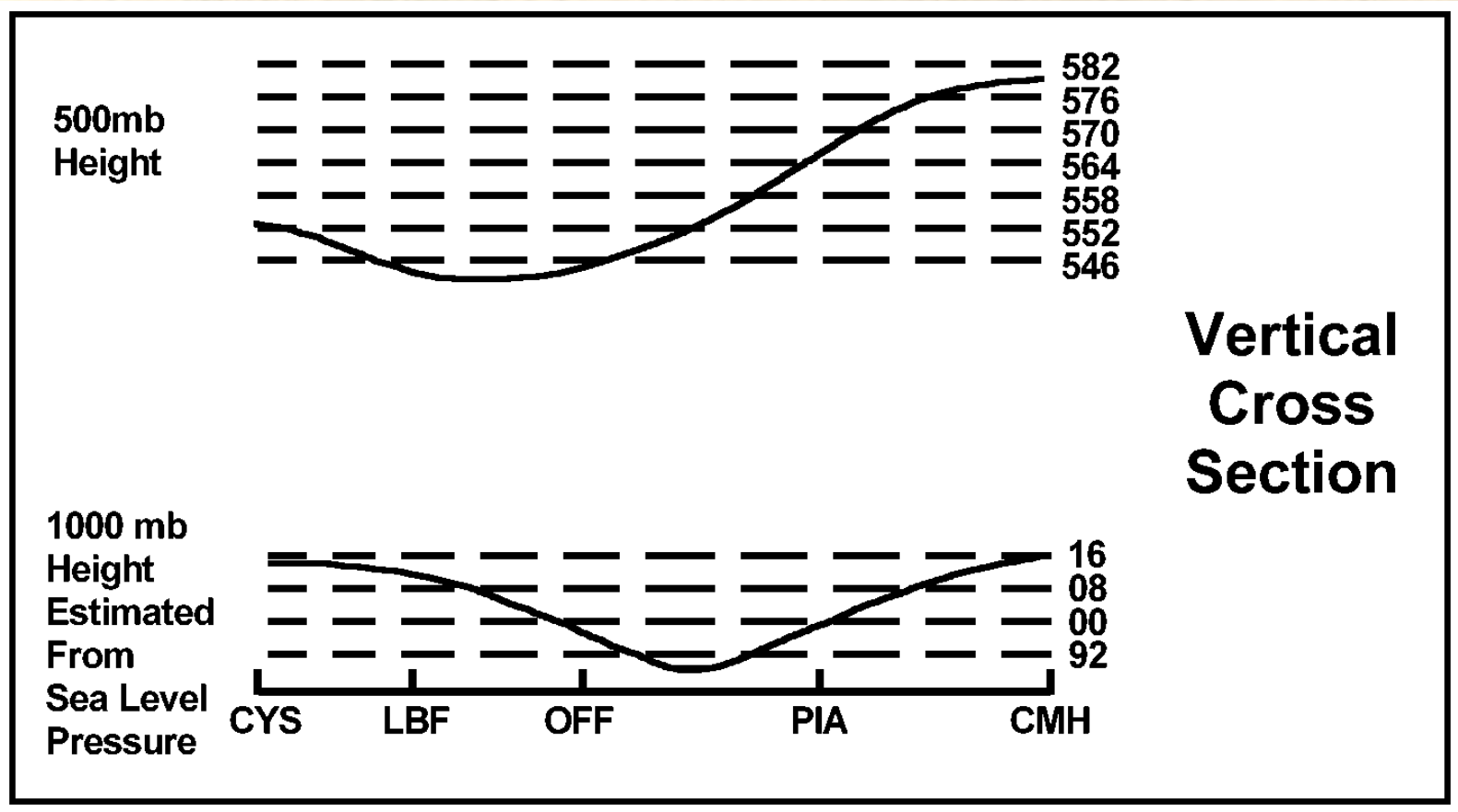
Slope of Constant-Pressure Surfaces

- **Vertical Cross-Section - Two-dimensional representation depicting vertical “slice” through atmosphere (already introduced earlier in Dynamics).**
- **Depict height of constant pressure surface AGL**

Slope of Constant-Pressure Surfaces

- **Manual Construction of Constant Pressure Surfaces**
  - Obtain pattern of upper-level constant pressure surface from 500-mb contours on 500-mb Heights/Vorticity chart
  - Obtain low-level constant pressure surface using surface pressures off SFC/1000-500-mb thickness chart

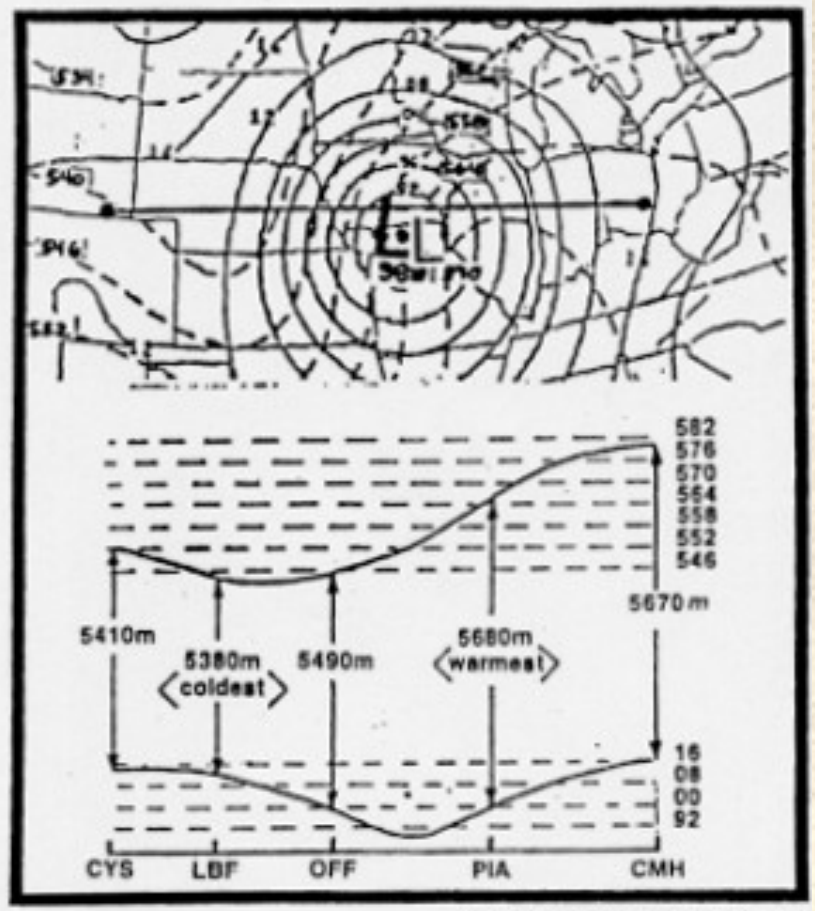
Vertical Cross Section



Slope of Constant-Pressure Surfaces

- **Thickness is distance between any two constant-pressure surfaces**
  - Commonly used thicknesses
    - 1000-500 mb - used to evaluate large-scale temperature pattern in lower atmosphere
    - 1000-850 mb - used to track cold, dense shallow air masses not extending above 850 mb
    - 850-500 mb - used in Western US where 1000-850-mb layer is below ground and 1000-500 mb is contaminated

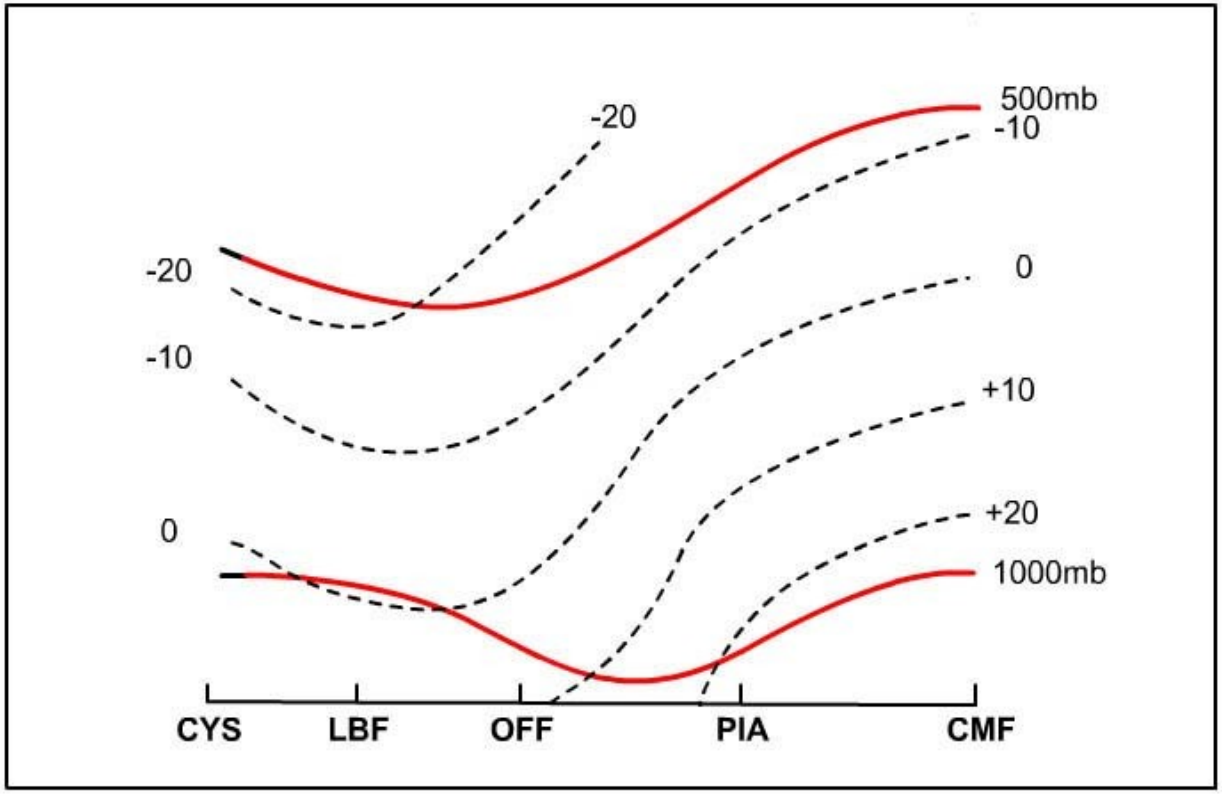
Thickness On A Vertical Cross Section



Slope of Constant-Pressure Surfaces

- Thickness on vertical cross-section
  - Low temperature = low thickness and the 1000-mb and 500-mb surfaces close together
  - High temperature = high thickness and the 1000-mb and 500-mb surfaces widely spaced

Isotherms On A Vertical Cross Section



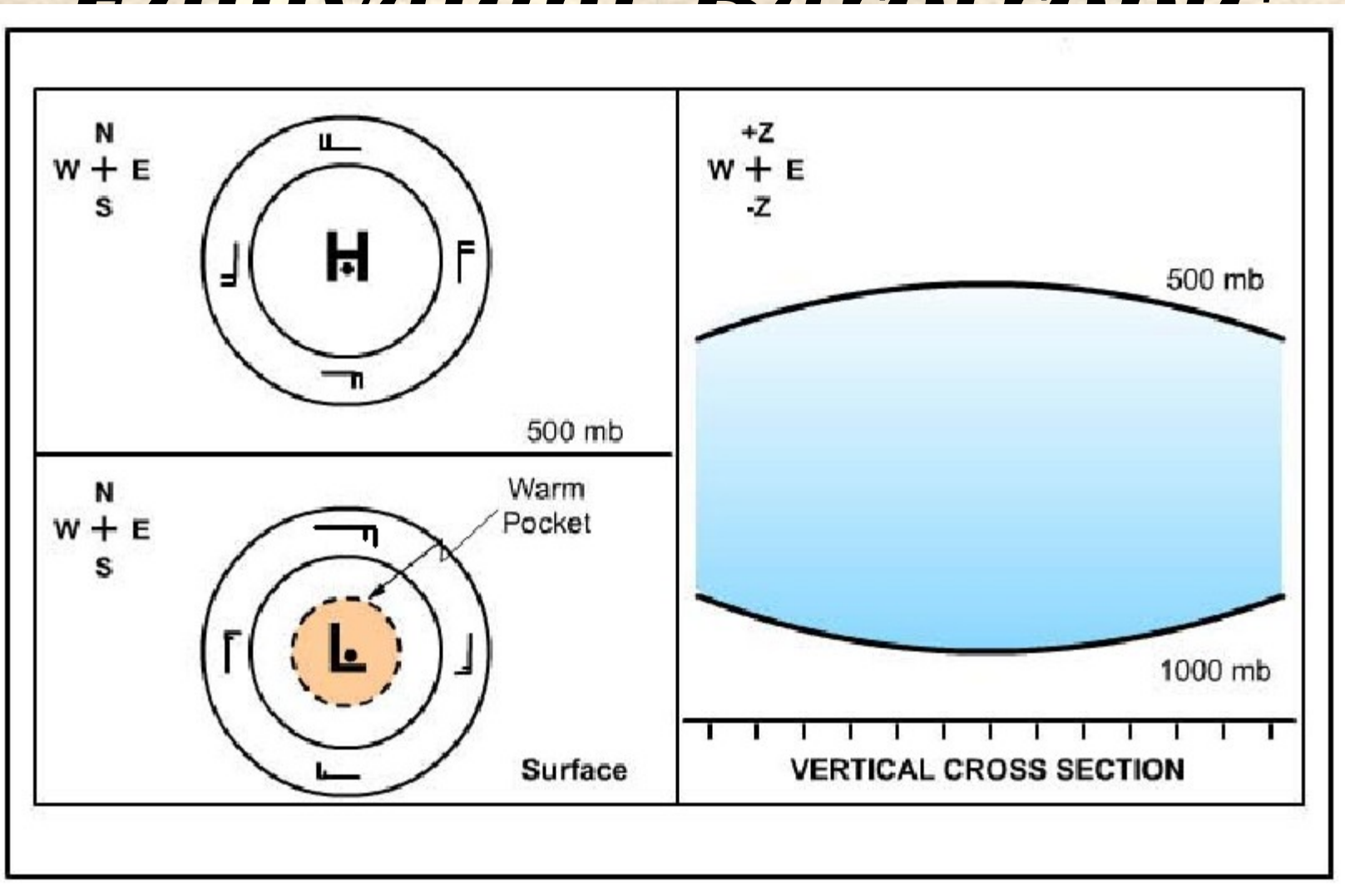
Slope of Constant-Pressure Surfaces

- Isotherms are sometimes included in vertical cross-section
  - Depicts temperature pattern in region of interest
  - Thickness reveals same information
- Isentropes are often displayed on a vertical cross section.

Equivalent Barotropic systems

- **Equivalent Barotropic Lows**
  - Warm Core Lows
    - Warmest air at center
      - The cyclone in the low to mid troposphere displays equivalent barotropic properties.
      - Thickness greatest at center
    - Vertically stacked in the lower and middle troposphere.
      - Mid-tropospheric reflection resides directly above surface low
      - High-pressure system may exist aloft above low pressure.

"Generic" Warm-Core Equivalent Barotropic



Equivalent Barotropic systems

- Cyclonic circulation weakens with height
  - Strongest cyclonic flow in low levels
  - Circulation aloft may reverse and become anticyclonic within upper-level high.
- No fronts
  - Warmest air at center
  - No air mass contrast

Equivalent Barotropic systems

- Caused by intense heating at center
- Precipitation and clouds (if any) are fairly symmetrical

Equivalent Barotropic systems

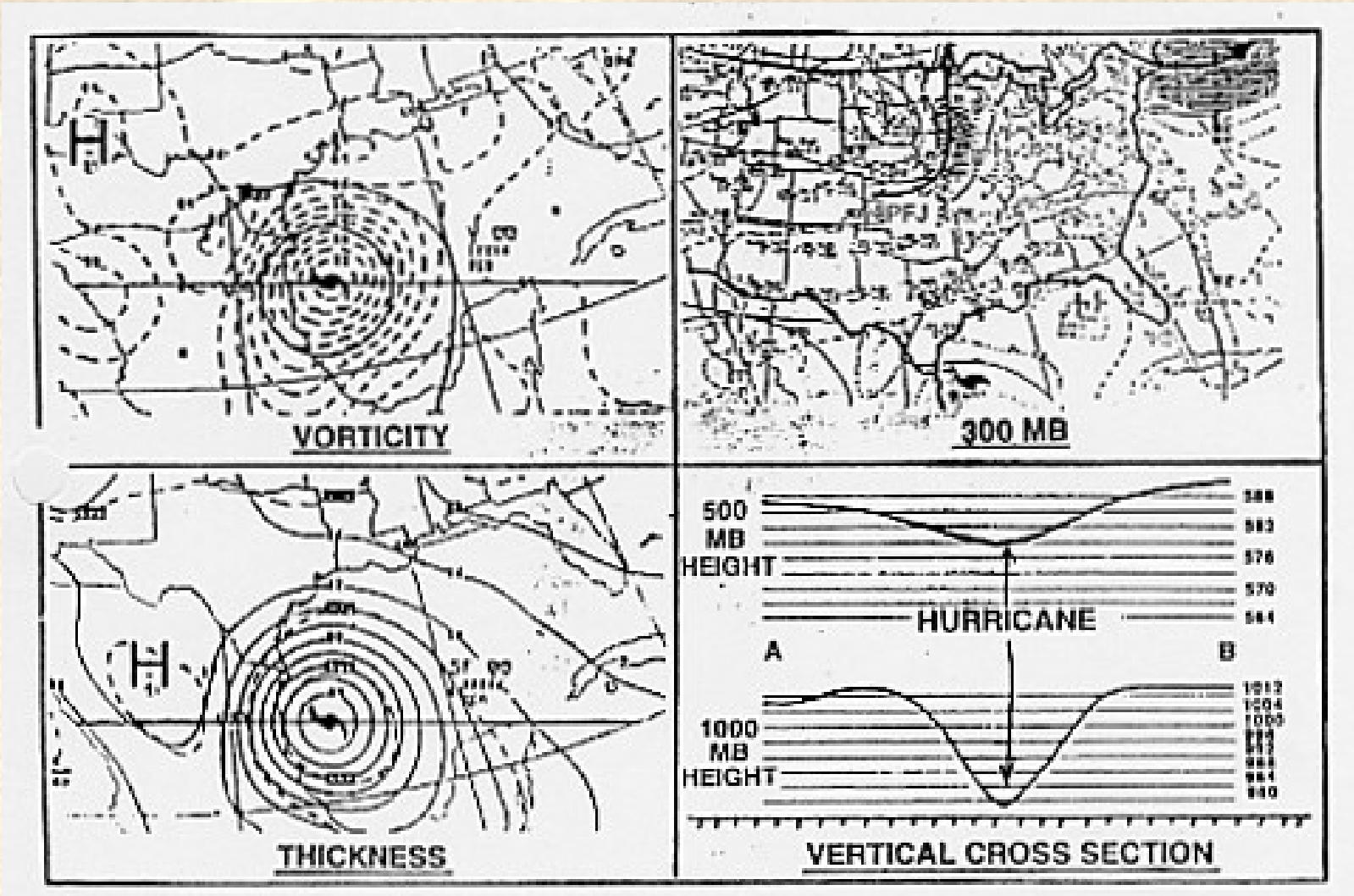
- Types of warm-core lows
  - Hurricanes/tropical storms/typhoons
    - » Intense convection with heavy precipitation.

      Sensible heat and moisture extracted from warm ocean

      Latent heat of condensation released

      Center heated
    - » Very low surface pressure and intense low-level wind circulation which weakens with altitude.
    - » Anticyclonic outflow in upper troposphere removes mass

Hurricane


H
VORTICITY
300 MB
H
THICKNESS
500
MB
HEIGHT
HURRICANE
A
B
1000
MB
HEIGHT
VERTICAL CROSS SECTION

Equivalent Barotropic systems

- Polar lows
  - Intense shallow convection or stratiform clouds with occasional intense precipitation.
    - » Sensible heat and moisture extracted from warmer ocean (note: ocean is warmer relative to extremely cold troposphere)..
    - » Latent heat of condensation/deposition released
    - » Center heated
  - Surface low pressure and wind circulation sometimes reaches tropical storm strength, but cyclonic circulation weakens with altitude.

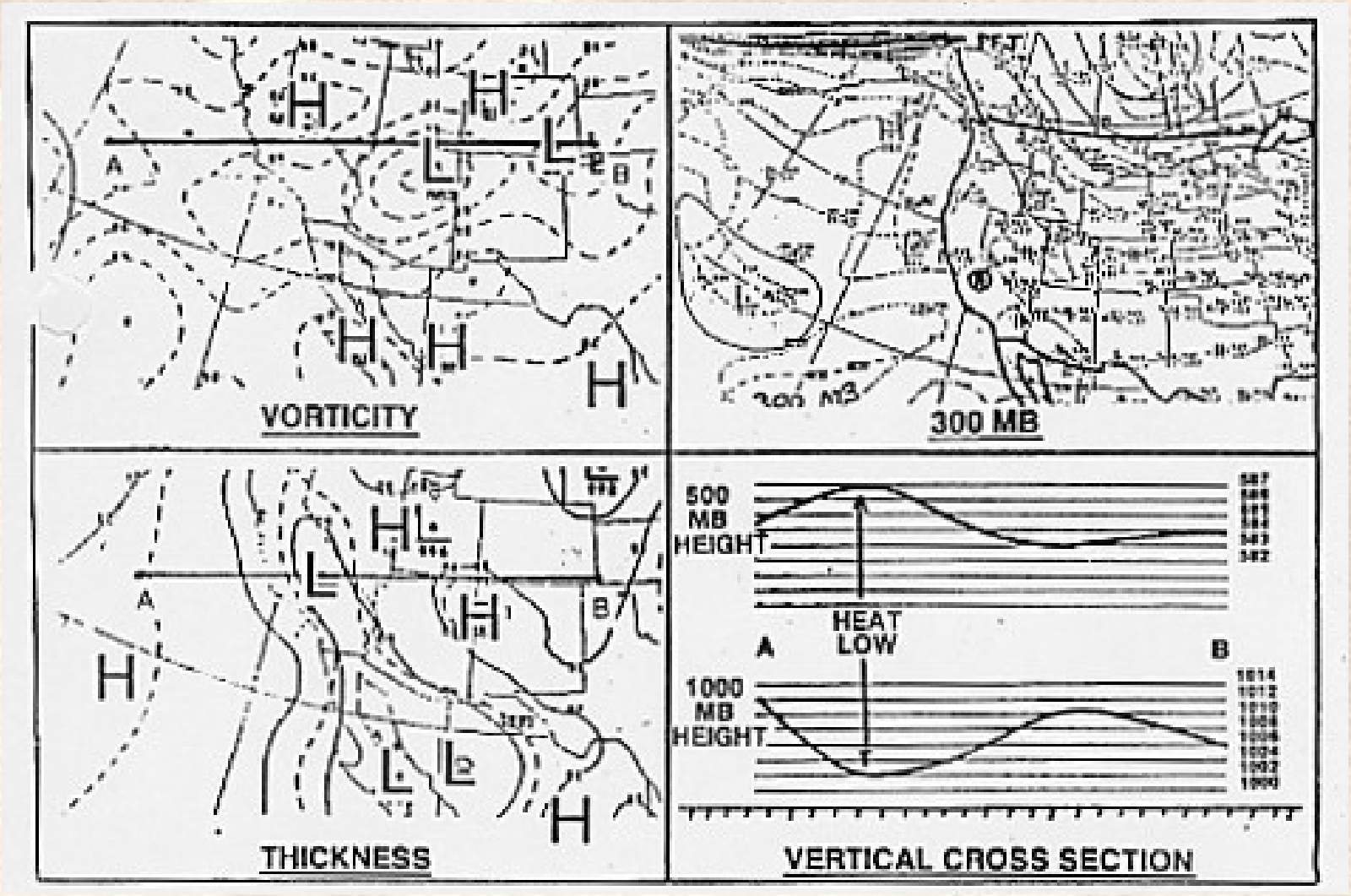
Equivalent Barotropic systems

- Heat (i.e., thermal) lows
  - Intense surface heating within a general region of mid-tropospheric subsidence and clear skies.
  - Low is very shallow and generally not well defined
  - Low will reposition to warmest surface, land or water
  - Weak surface circulation further weakens with height
    - » In mid and upper levels, a ridge exists
    - » Heat low forms under a mid and upper-tropospheric ridge, but unlike tropical cyclones, the dryness and lack of latent heat release prevents the heat low from making or enhancing the mid and upper-level ridge

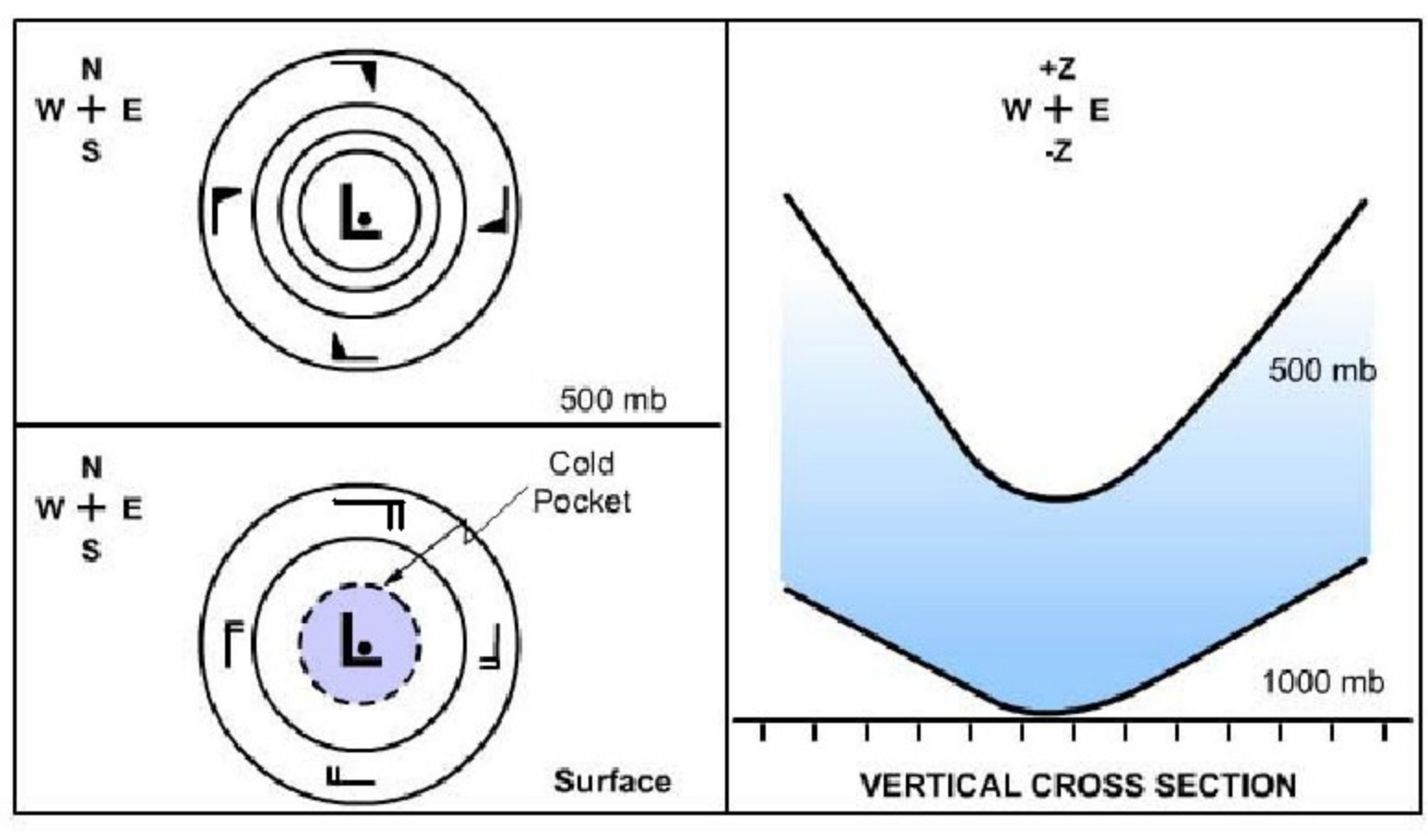
Equivalent Barotropic systems

- Weather
  - » Day - thermals develop
  - » Precipitation scarce
  - » Possible afternoon thunderstorms mainly produced by elevated heating over mountains.

Heat Low


VORTICITY
300 MB
THICKNESS
500 MB HEIGHT
HEAT LOW
A
B
1000 MB HEIGHT
VERTICAL CROSS SECTION

"Generic" Cold-Core Equivalent Barotropic Low



Equivalent Barotropic systems

- Cold Core Equivalent Barotropic Lows
  - Coldest air at center
    - The cyclone often displays equivalent barotropic properties throughout the troposphere.
    - Thickness lowest at center
  - Vertically stacked
    - Surface lows typically poorly defined and may not exist at all
    - Low thickness at center, upper level circulation often is most intense

Equivalent Barotropic systems

- Cyclonic circulation strengthens with height, wind speed increases
- No fronts
  - Coldest air at center
  - No air mass contrast
- May be either equatorward or poleward of PFJ

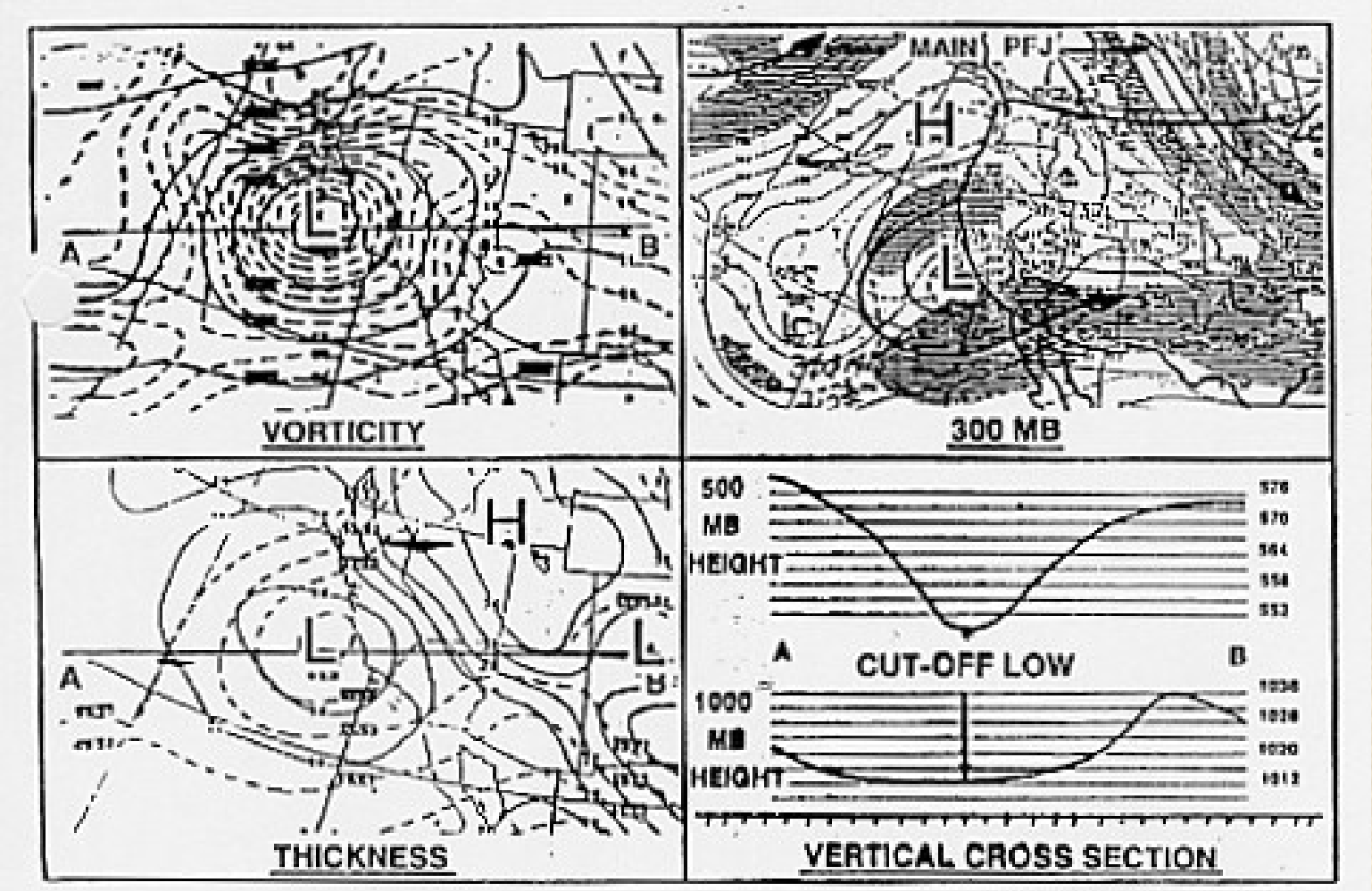
Equivalent Barotropic systems

- Weather is relatively symmetrical
  - Generally cloudy skies with scattered mainly stratiform precipitation
  - Minor short waves
    - » Rotating around low
    - » Bands of precipitation

Equivalent Barotropic systems

- Two main types of cold-core equivalent barotropic lows are seen on weather charts
  - Cut-off low
  - Decaying Wave

“Cut-off” Low


VORTICITY
MAIN PFJ
300 MB
THICKNESS
500 MB HEIGHT
CUT-OFF LOW
1000 MB HEIGHT
VERTICAL CROSS SECTION

Equivalent Barotropic systems

- Cut-off Low
  - Equatorward of main PFJ
  - Often forms within t deepening trough when:
    - » cold air mass is transported to low latitudes via cold advection; thus lowering the heights of isobaric surfaces there.
    - » conservation of absolute vorticity requires air moving from polar to subtropical regions to increase it's cyclonic spin (i.e., cyclonic relative vorticity is enhanced..
  - Jet re-orients to zonal pattern and cuts off cold air from main pool

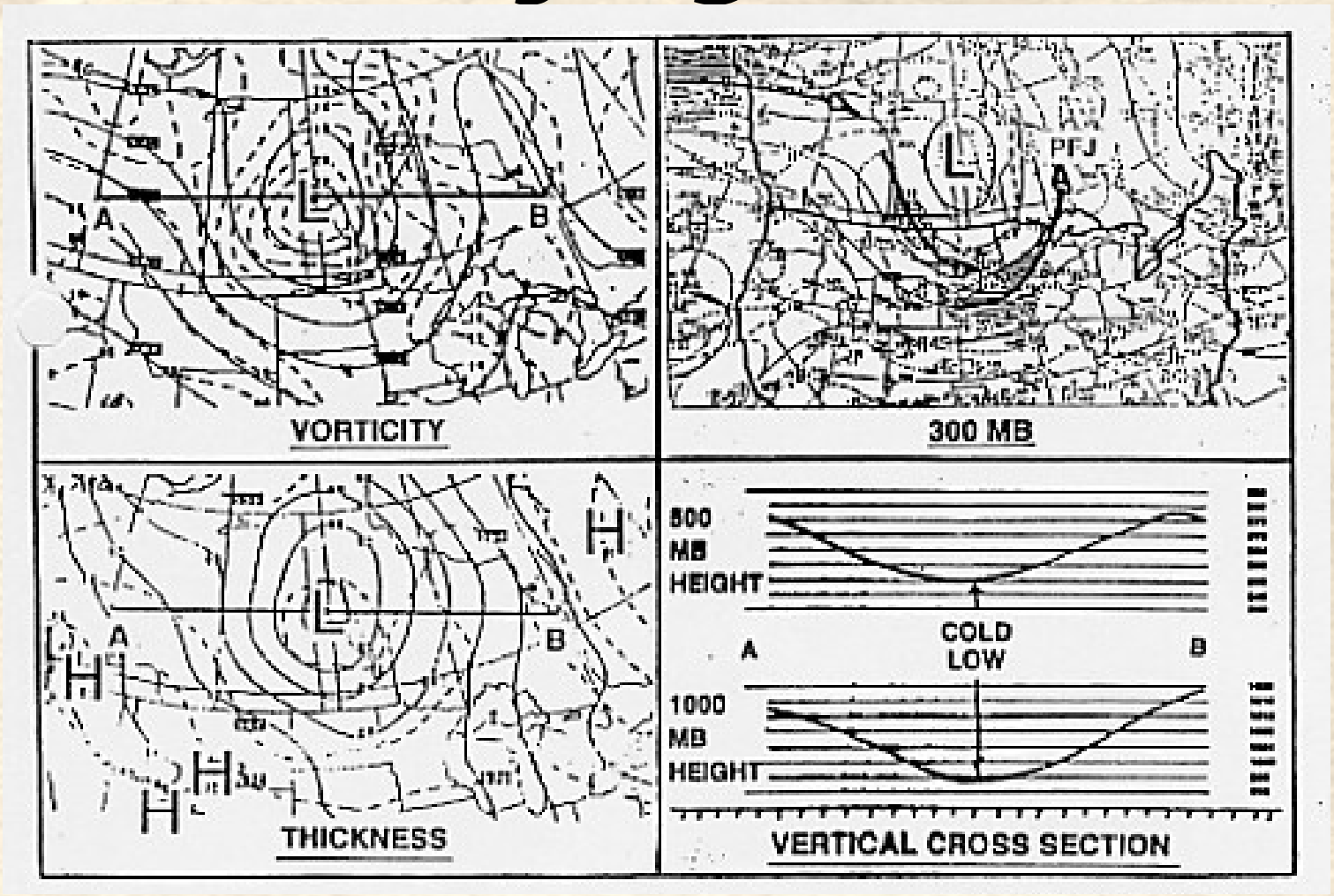
Equivalent Barotropic systems

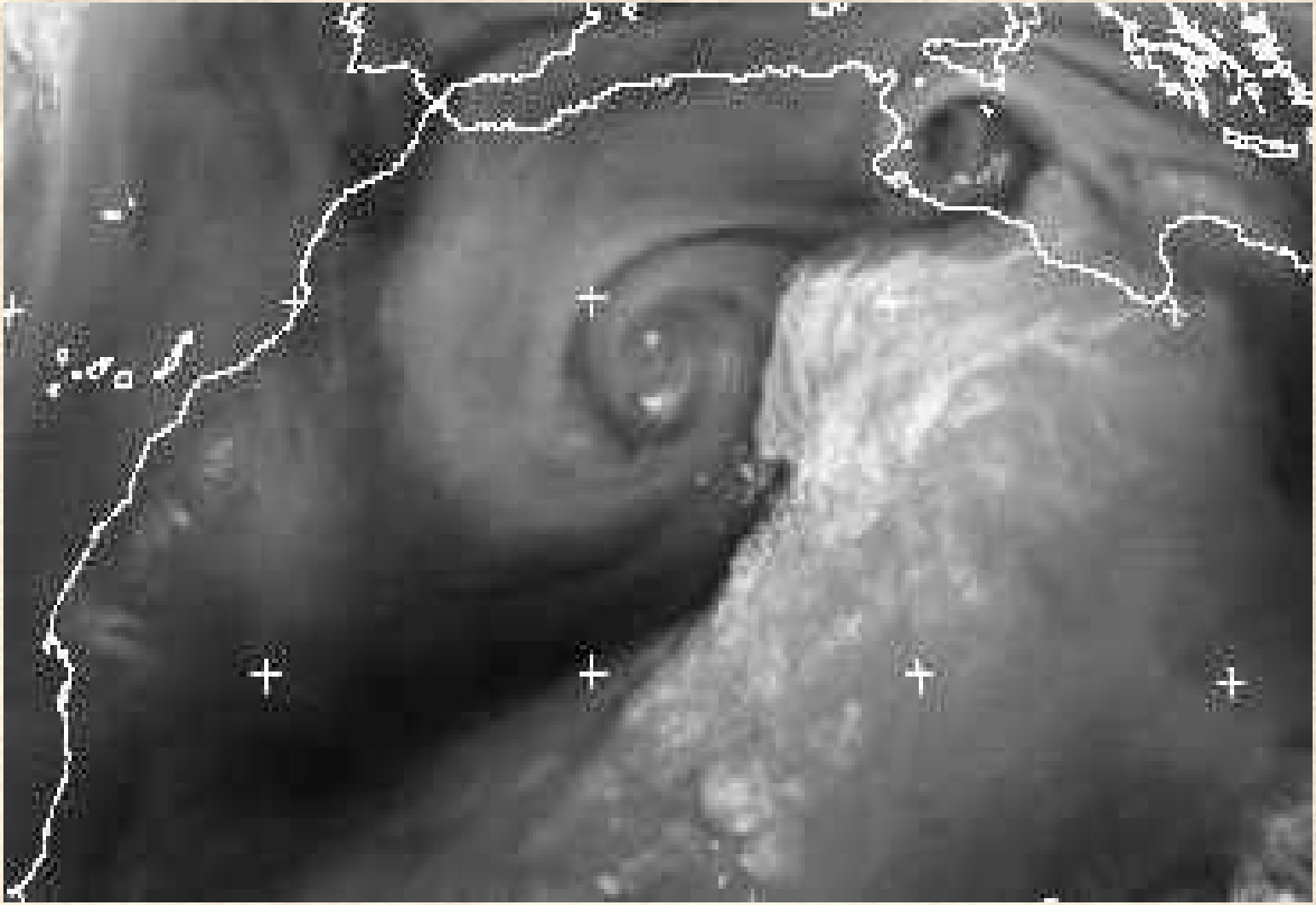
- Most common in subtropics off the west coast of continents (such as the southwest US); can occur anywhere geographically when above formation conditions exist
- Most common in spring, but may be seen throughout year
  - » During spring, cold air frequently moves south in deep long-wave troughs
  - » Cold air can easily "cut-off" if jet reforms to north
  - » Jet typically migrates northward during spring

Equivalent Barotropic systems

- One of three things can happen to cut-off lows
  - » remains almost stationary due to the lack of significant vorticity and thermal advection. System may slowly dissipate.
  - » may retreat westward on the equatorward side of the subtropical high.
  - » if new trough approaches from west, the cut-off low “opens up” into short-wave trough and newly-developed positive vorticity advection allows system to prograde eastward. Upstream trough referred to as a “kicker” short-wave.

Decaying Wave





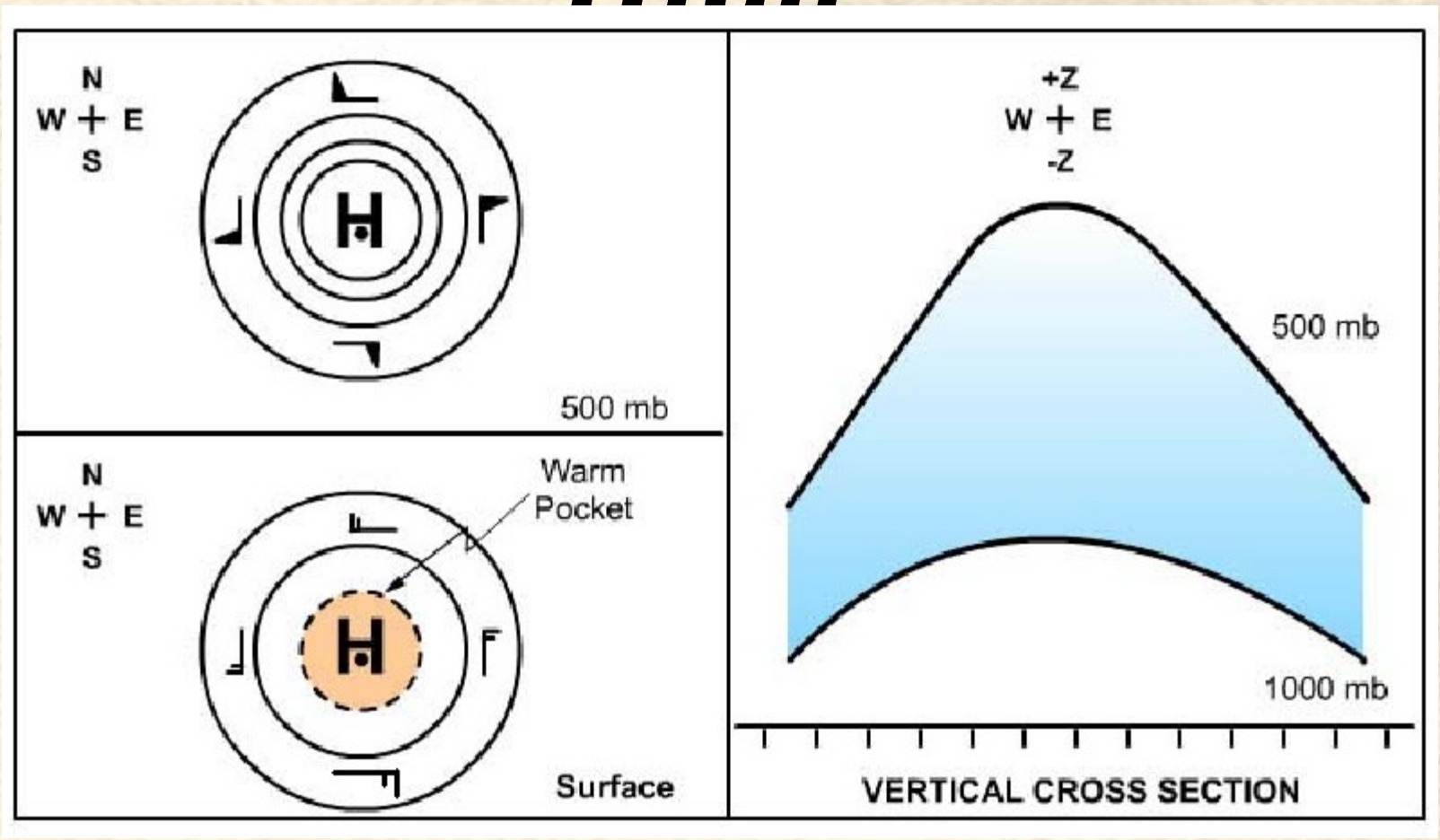
Equivalent Barotropic systems

- Decaying Wave
  - Located poleward of PFJ
  - Low in Dissipation Stage of life cycle
  - Favored locations: Aleutian Island or Iceland Region
    - » Deep, slow moving and remain in the region for a long time
    - » Areas are dominated by low pressure
    - » Sometimes found in Hudson Bay region

Equivalent Barotropic systems

- Persistent large cold-core equivalent barotropic cyclonic vortices may persist for long periods as part of a long-wave trough due to a dynamic geostrophic balance of wind and height patterns between the polar easterlies and mid-latitude westerlies.

"Generic" Warm-Core Equivalent Barotropic High



Equivalent Barotropic systems

- **Equivalent Barotropic Highs**
  - Warm-Core Equivalent Barotropic Highs
    - Warmest air at center
      - » Referred to as warm-core highs
      - » Thickness greatest at center
      - » Warming is the result of compressional heating due to subsidence within the high.

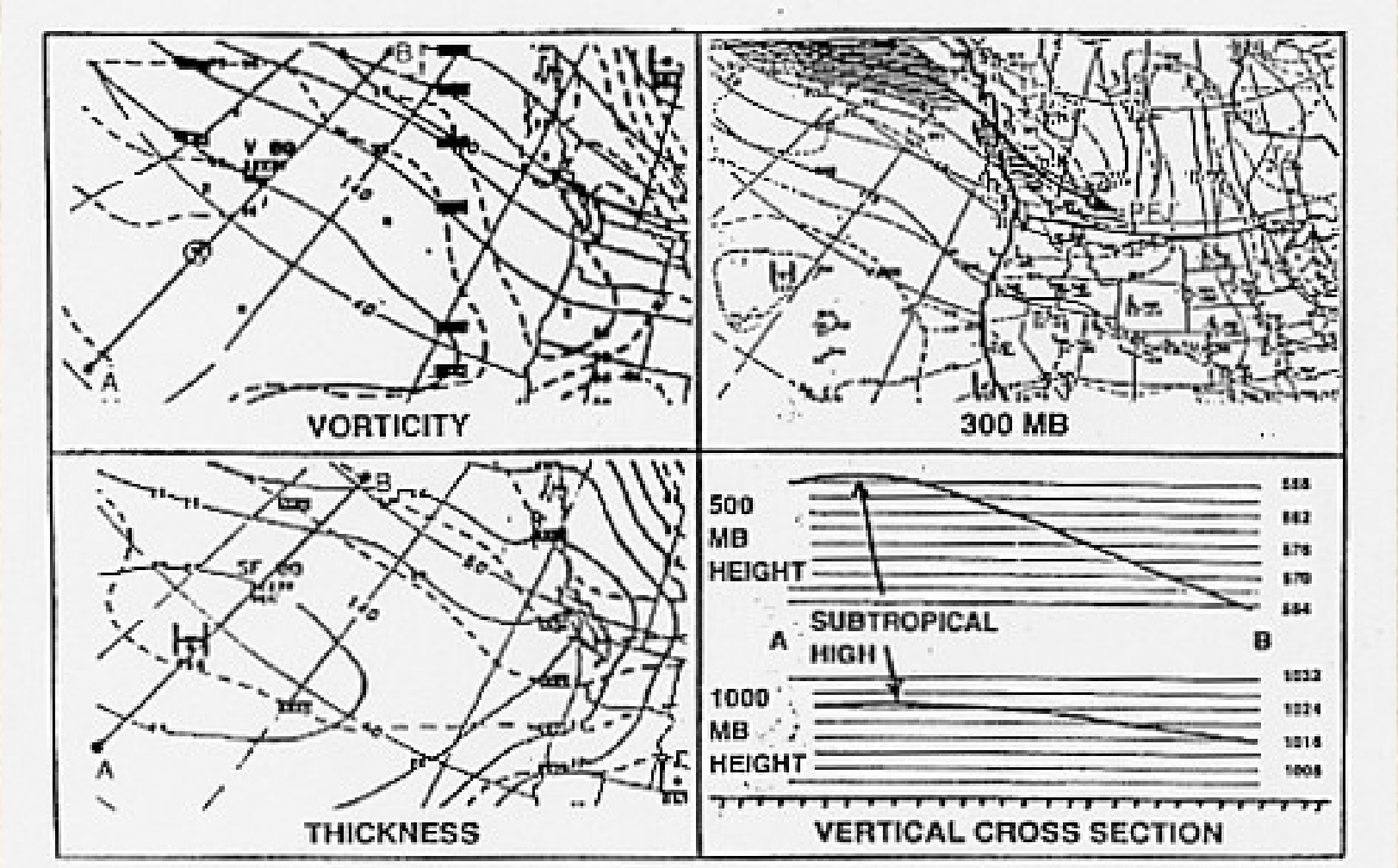
Equivalent Barotropic systems

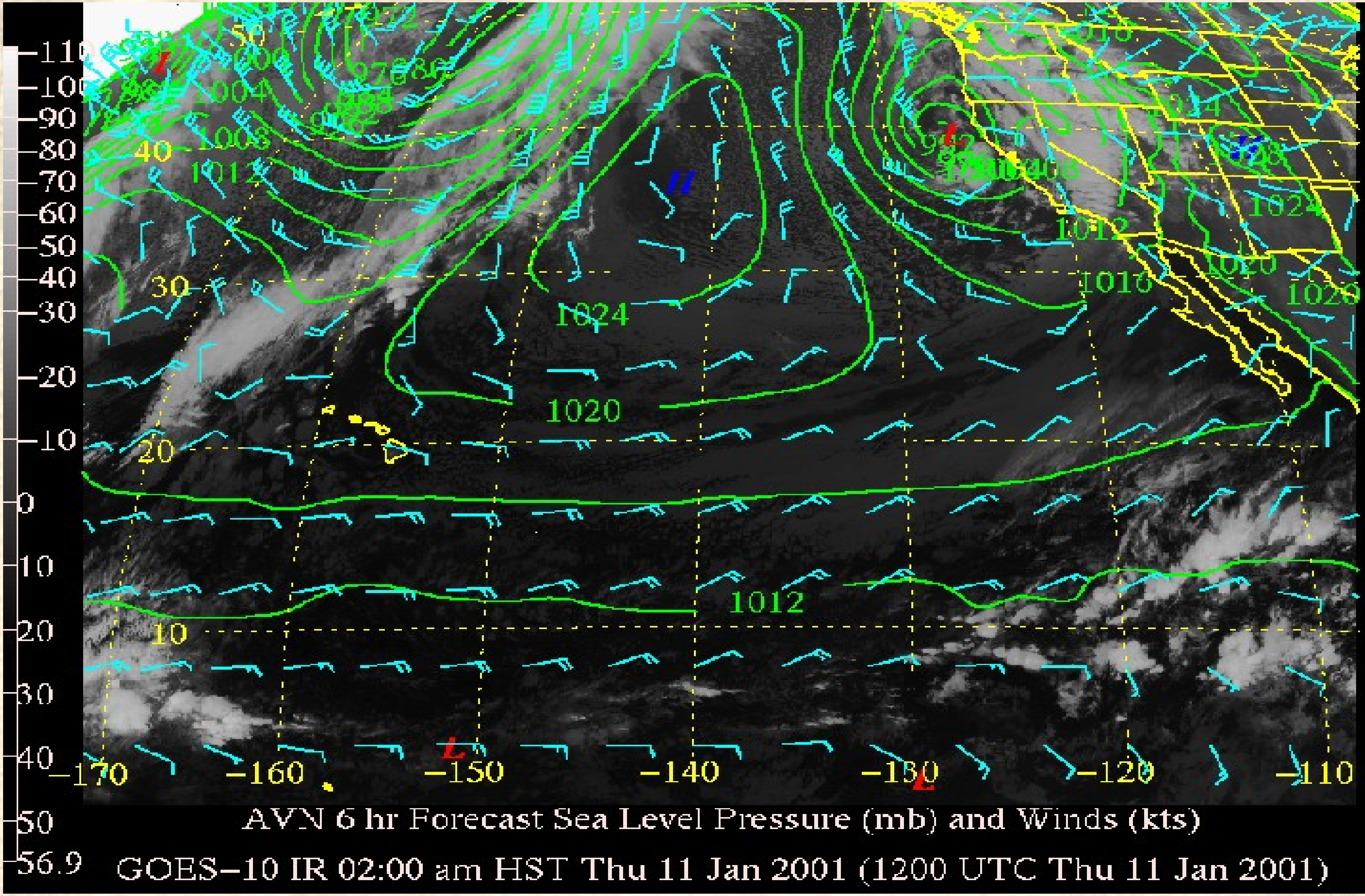
- System is vertically stacked
  - » Surface high may not be well defined
  - » Anticyclonic circulation strengthens with height
  - » Wind speed increases with height
- Slope of isobaric surfaces increases with height (i.e., height gradient increases with height).
- May occur either equatorward or poleward of PFJ
- System is result of large-scale circulation
- Weather is typically dry and warm due to large-scale subsidence and associated subsidence inversion.

Equivalent Barotropic systems

- Two main types of warm-core barotropic highs are seen on weather maps, however, a third “special” type of warm core high may have a cold shallow surface layer, overlain by a deep relatively-warm troposphere aloft.
  - » Subtropical highs
  - » Cut-off highs
  - » Cold Surface Warm High (Special Case)

Subtropical High




1024
1020
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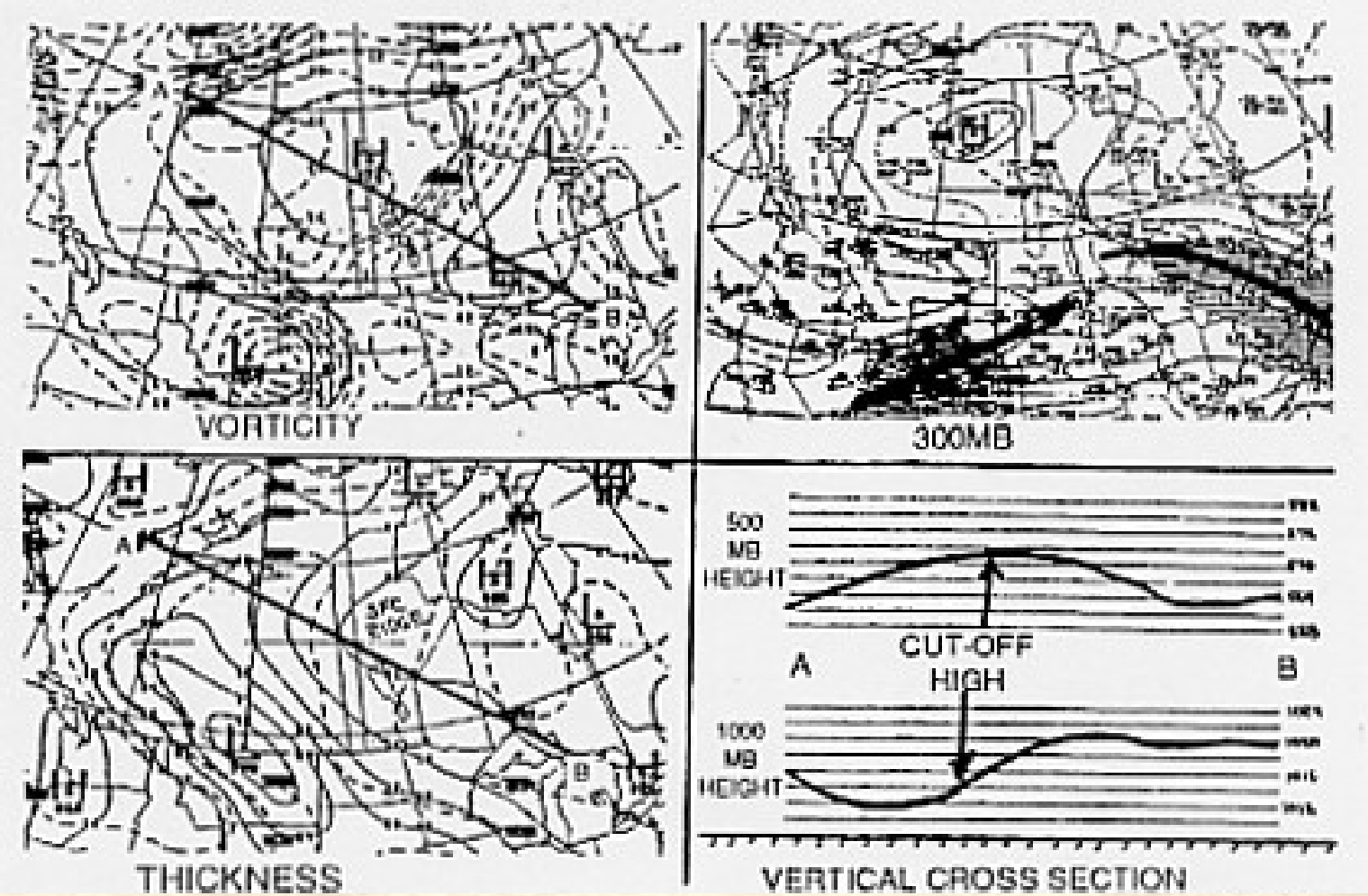
-140
-130
-120
-110
AVN 6 hr Forecast Sea Level Pressure (mb) and Winds (kts)
GOES-10 IR 02:00 am HST Thu 11 Jan 2001 (1200 UTC Thu 11 Jan 2001)

Equivalent Barotropic systems

- Subtropical High
  - Located equatorward of PFJ
  - Caused by:
    - » Convergence of Hadley and Ferrel Cells
    - » Persistent large warm-core equivalent barotropic anticyclones persist for long periods a part of long-wave ridges due to a dynamic geostrophic balance of wind and height patterns between the mid-latitude westerlies and trade winds.
  - Diffuse area of high pressure near 30◦N

Cut-off (Blocking) High



Equivalent Barotropic systems

- Cut-off highs
  - Also referred to as “blocking” highs
  - Located poleward of PFJ mean position.
  - Surface high not always well defined

Equivalent Barotropic systems

- Often forms ahead of a major mid-latitude cyclone as.
  - » warm air mass is transported to high latitudes via warm advection; thus raising the heights of isobaric surfaces there.
  - » conservation of absolute vorticity requires air moving from tropical to polar regions to increase it's anticyclonic spin (i.e., cyclonic relative vorticity is enhanced).
- Jet re-orients to more high zonal pattern

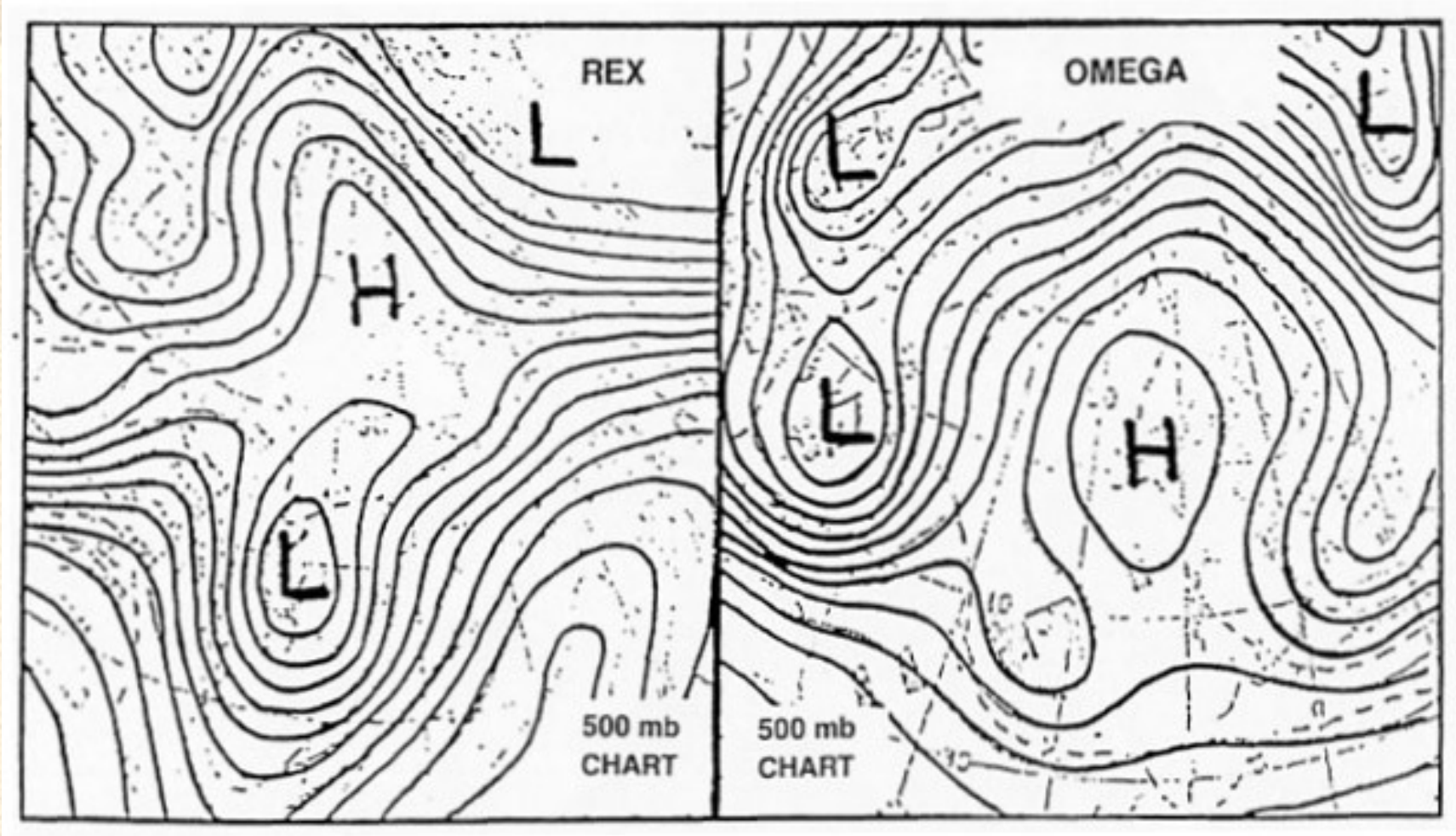
Equivalent Barotropic systems

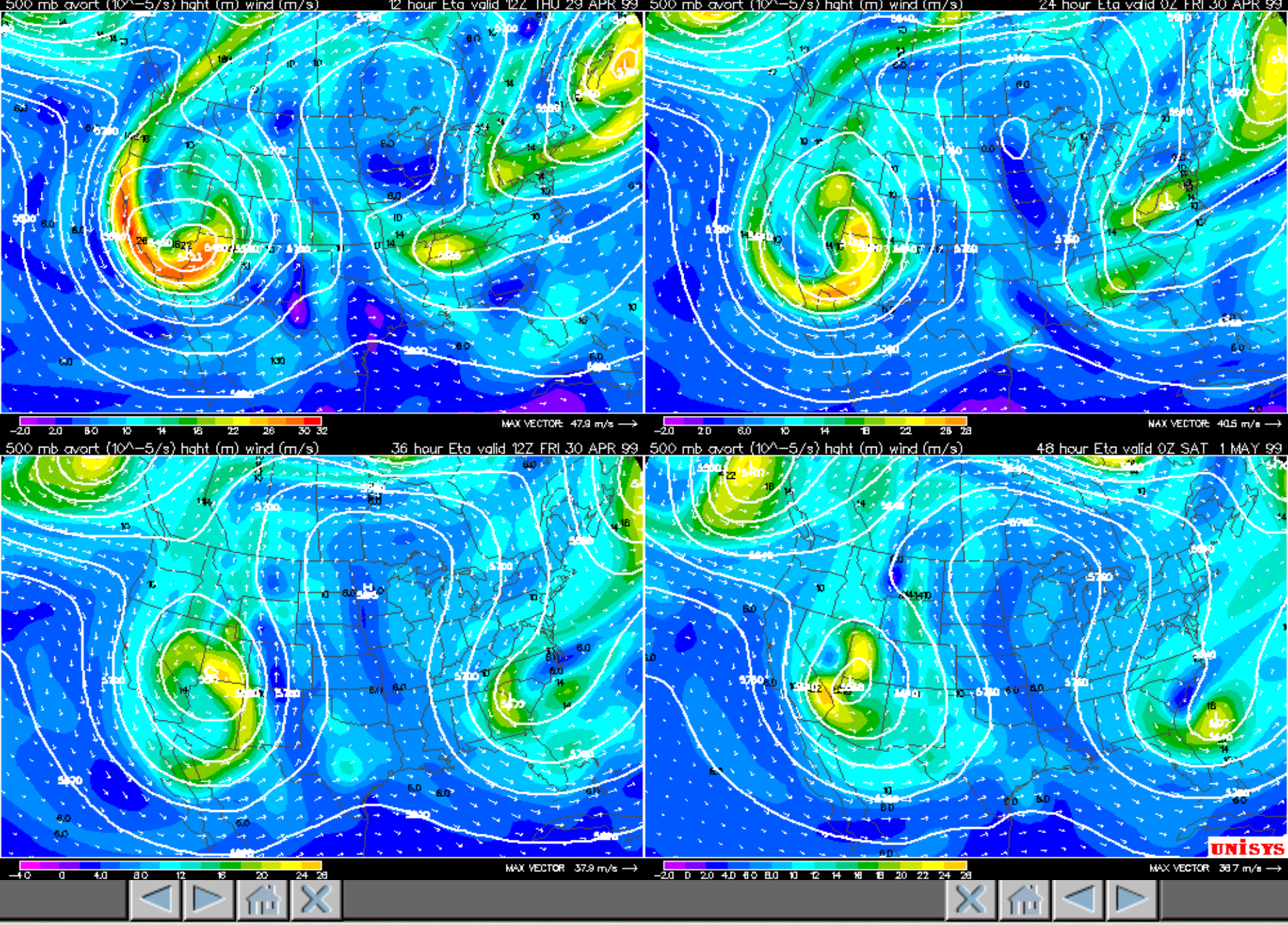
- Most common in higher latitudes over eastern oceans off the west coast of continents (such as off the west coasts of North America and Europe.
- Most common in the Northern Hemisphere, due to greater amount of land masses and mid-latitude mountain ranges, compared to the Southern Hemisphere.

Equivalent Barotropic systems

- Two common patterns
  - » Omega Block - resembles Greek letter
  - » Rex Block - high positioned poleward of low translating east - best developed when a cut-off high is positioned directly poleward of a cut-off low.

Classic Blocking Patterns

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24 hour Eta valid 0Z FRI 30 APR 99
MAX VECTOR 40.5 m/s
500 mb avort (10^-5/s) hght (m) wind (m/s)
36 hour Eta valid 12Z FRI 30 APR 99
MAX VECTOR 37.9 m/s
500 mb avort (10^-5/s) hght (m) wind (m/s)
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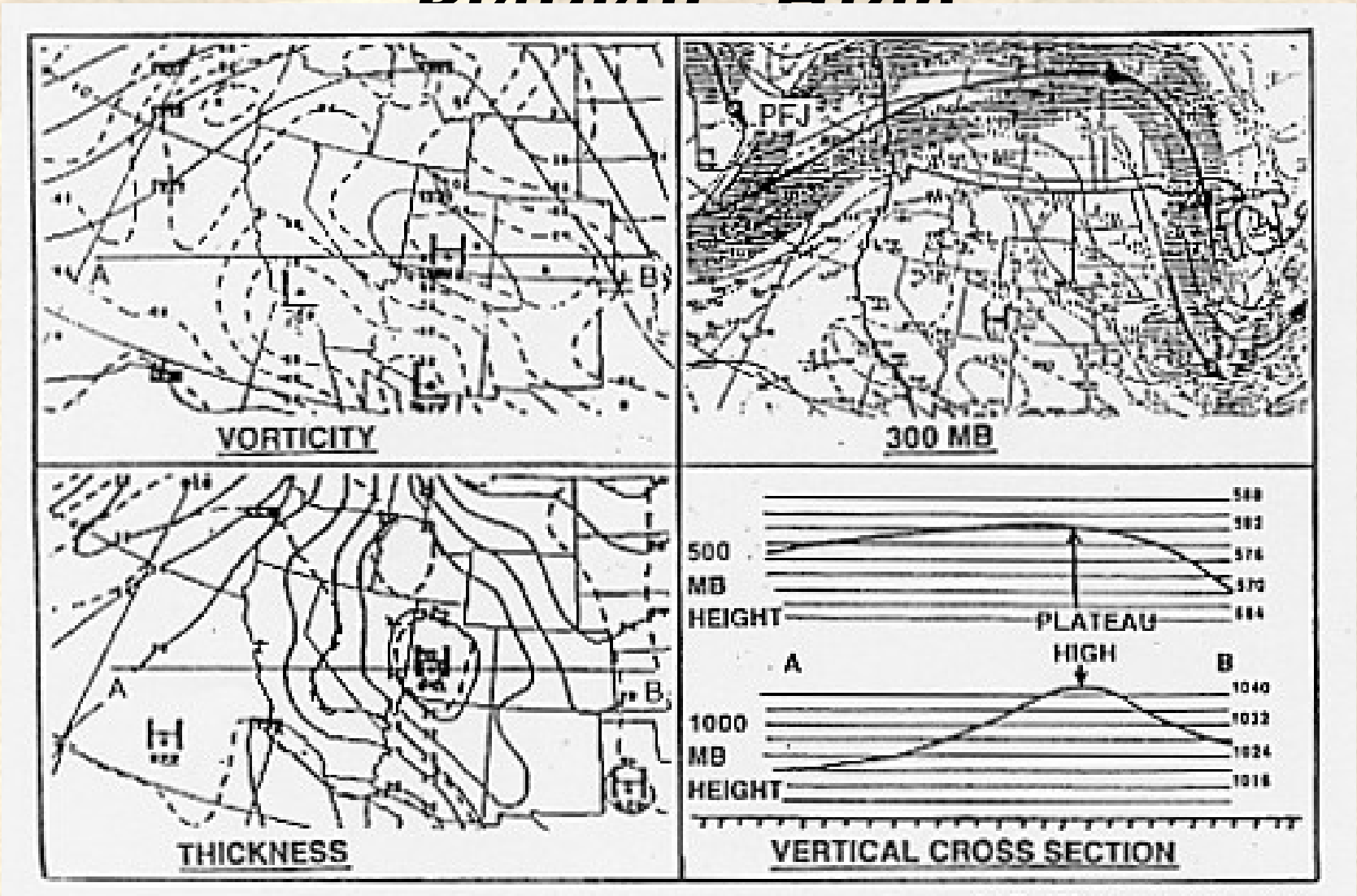
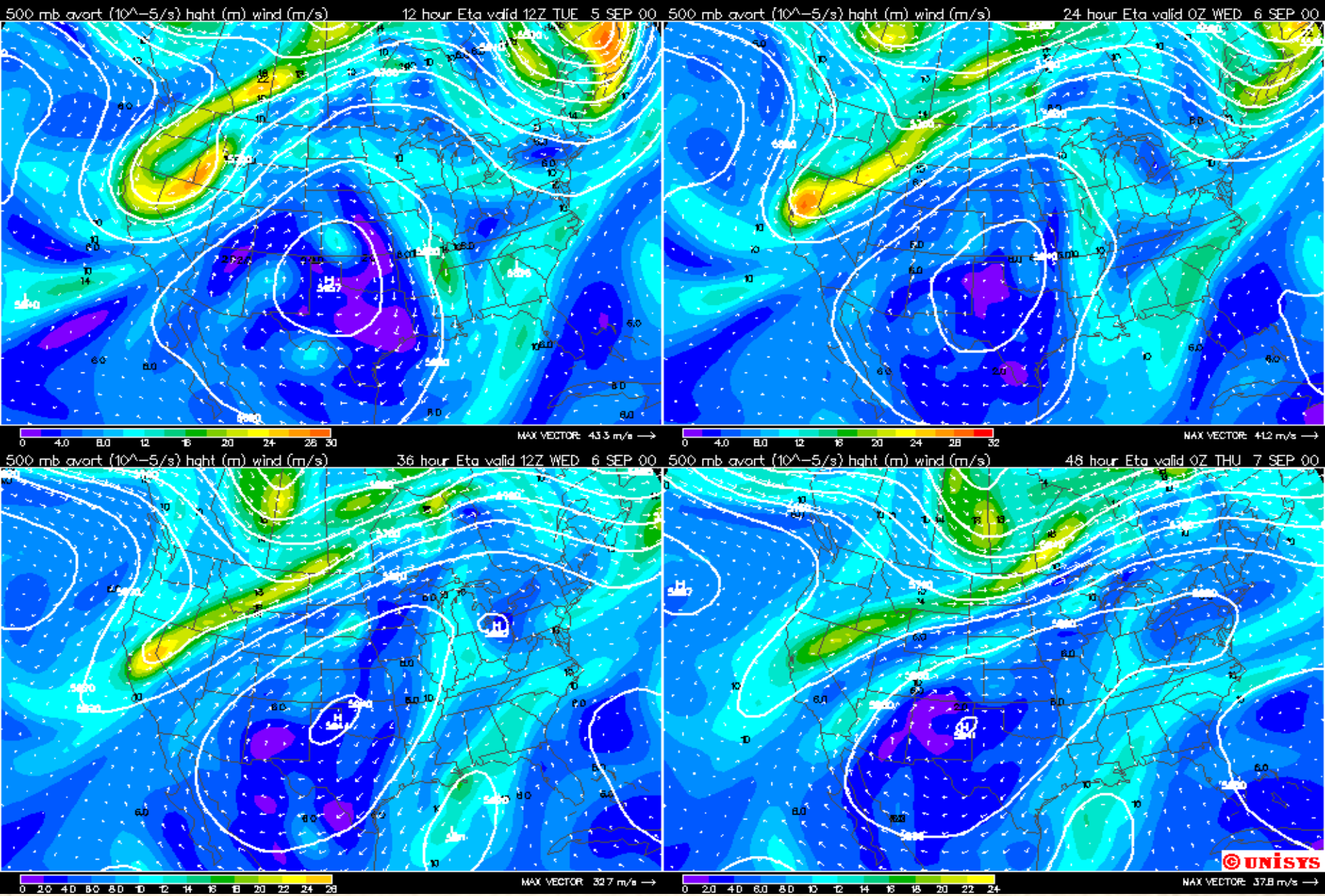
Cold-Surface Warm-Core "Plateau" High




500 mb avort (10^−5/s) hght (m) wind (m/s)
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36 hour Eta valid 12Z WED 6 SEP 00
MAX VECTOR 32.7 m/s
500 mb avort (10^−5/s) hght (m) wind (m/s)
48 hour Eta valid 0Z THU 7 SEP 00
MAX VECTOR 37.8 m/s
©UNISYS

Equivalent Barotropic systems

- Cold-Surface Warm-core High
  - Referred to as “Special Case”
  - Forms in over land generally in winter. Two general types: Mid-latitude and high latitude.
    - In middle-latitudes, generally found in elevated plateau regions surrounded by higher mountains.
      - » Normally under the mid-upper tropospheric subtropical ridge equatorward of the PFJ and polar front.
      - » Normally strongest during early morning hours after night-long radiational cooling.

Equivalent Barotropic systems

- Common in the inter-mountain region of the western United States where air becomes trapped between Sierra-Nevada and Rocky Mountains for long periods of time.
- Pollution is trapped within stable stagnant air near the surface, resulting in bad air quality.

Equivalent Barotropic systems

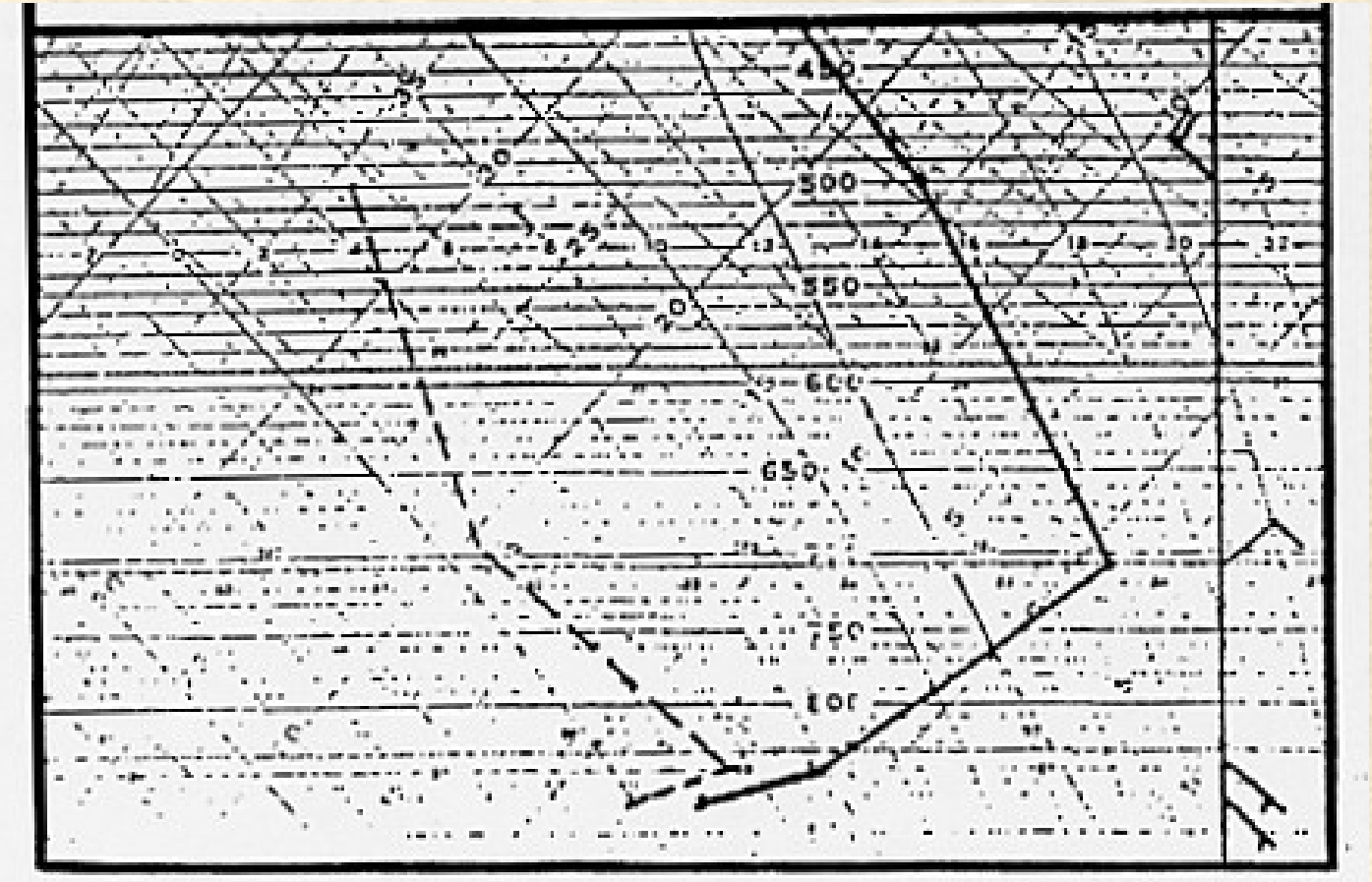
- In high latitudes, generally found over relatively flat snow-covered ground.
  - » Normally under mid-upper tropospheric blocking high poleward of the PFJ and polar front.
  - » Most common in cP and cA source regions over northern Asia (i.e., Siberia).

- Warm ridge aloft promotes persistent stagnant weather pattern with light winds.

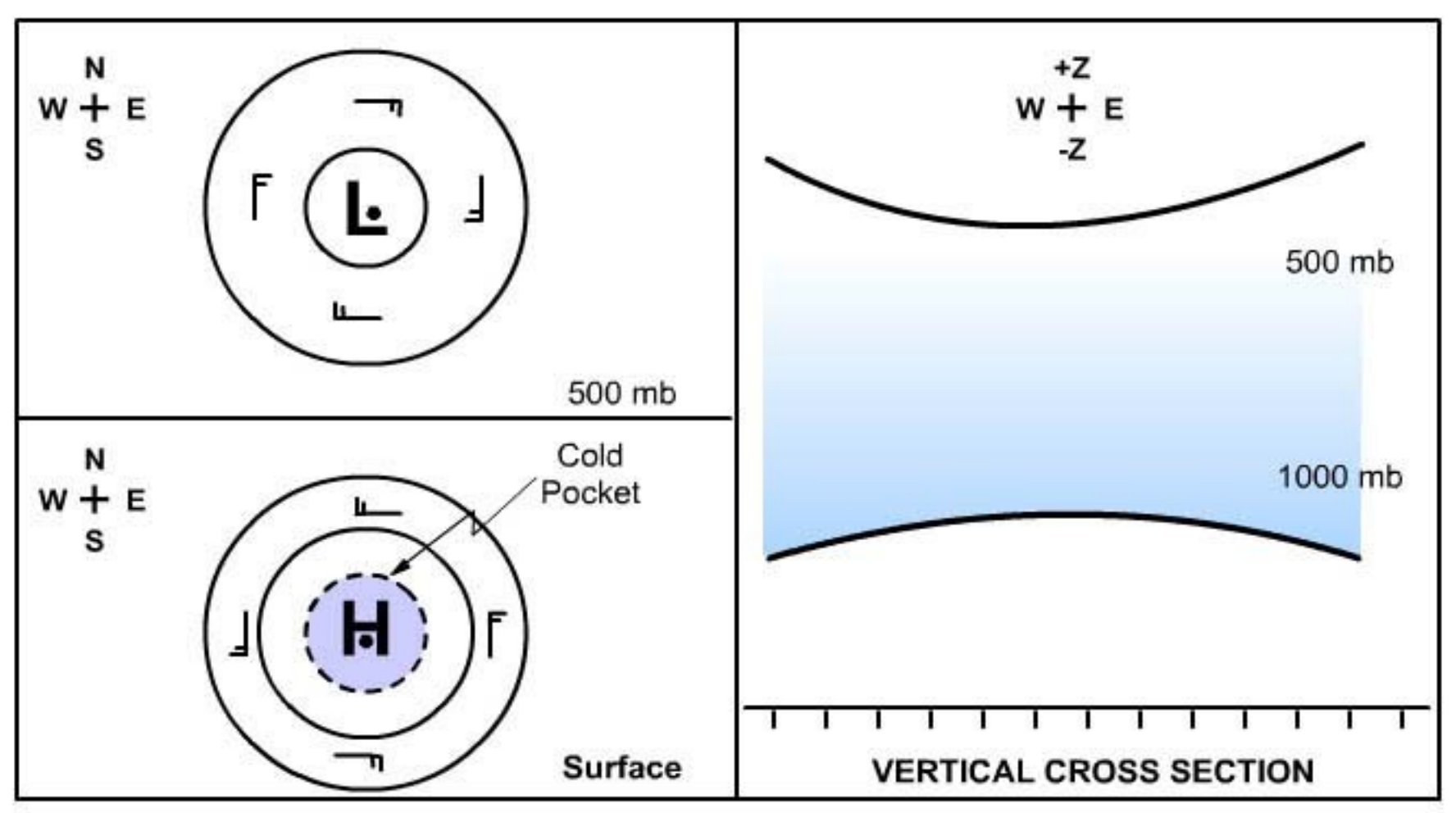
Equivalent Barotropic systems

- Deep subsidence aloft promotes
  - subsidence inversion
  - clear skies and strong radiational cooling of surface during long nights promotes intense radiation inversion near surface and development of extremely cold cA air masses.
- Radiation inversion at surface, and subsidence inversion in lower troposphere separate cold surface high from warmer high aloft.
- Persists in same area for long periods

SKEW-T Through a Plateau High



"Generic" Cold-Core Equivalent Barotropic High



Equivalent Barotropic systems

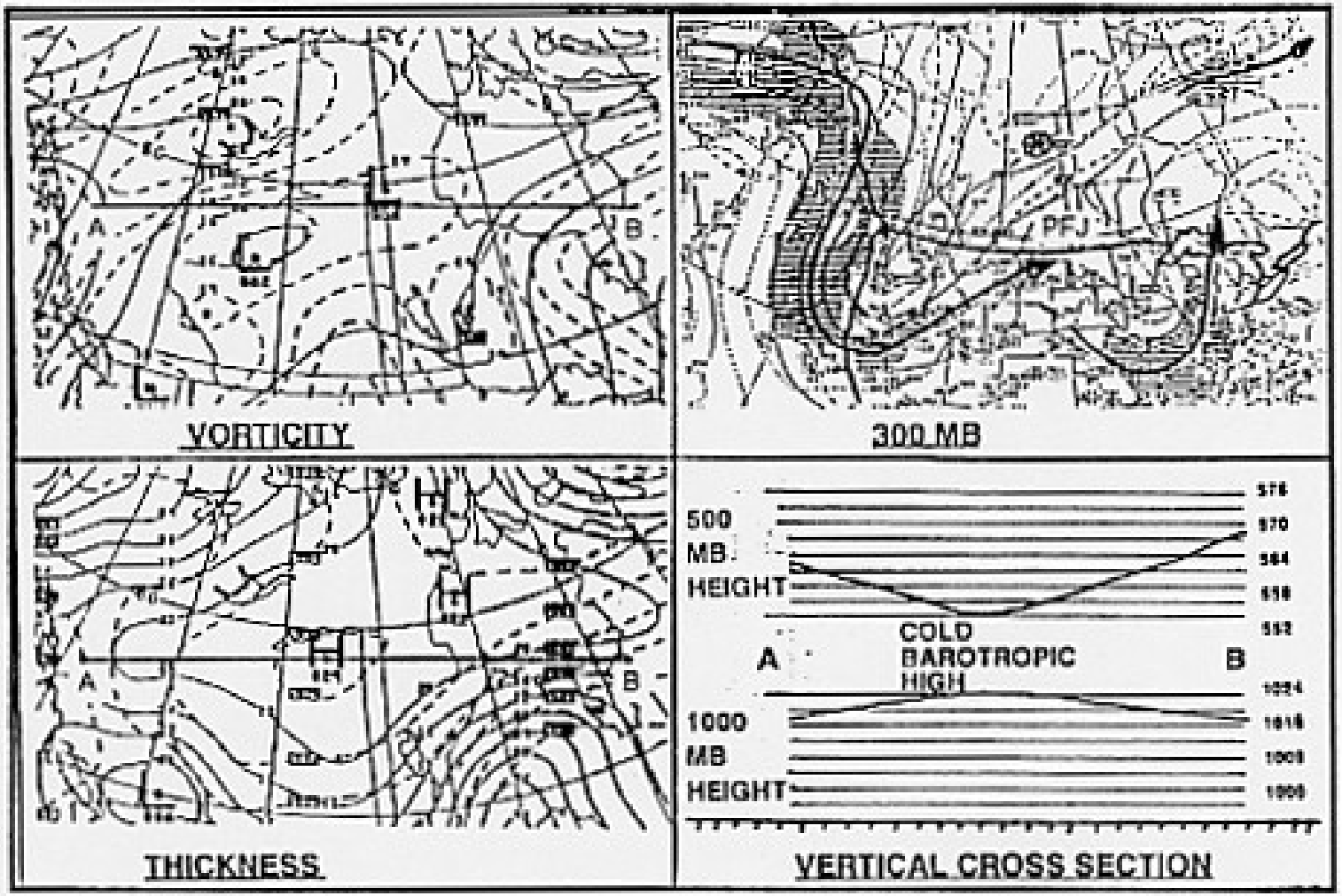
– Cold Core Equivalent Barotropic Highs

- Formed from intense surface cooling beneath very cold mid-upper troposphere.
- Coldest air at center
- Thickness lowest at center
- Vertically stacked through the lower and middle troposphere.
- Due to low thickness, low may exist in upper levels

Equivalent Barotropic systems

- Anticyclonic circulation weakens with height
- Strongest anticyclonic flow in low levels
- Circulation aloft may become cyclonic as slope reverses
- No fronts

Polar Cold-Core Equivalent Barotropic High



Equivalent Barotropic systems

- Poleward of PFJ
- Cold weather
- Forms in cP source region
- Climatologically favored locations
  - Northern Canada
  - Northeast Asia (Siberia)

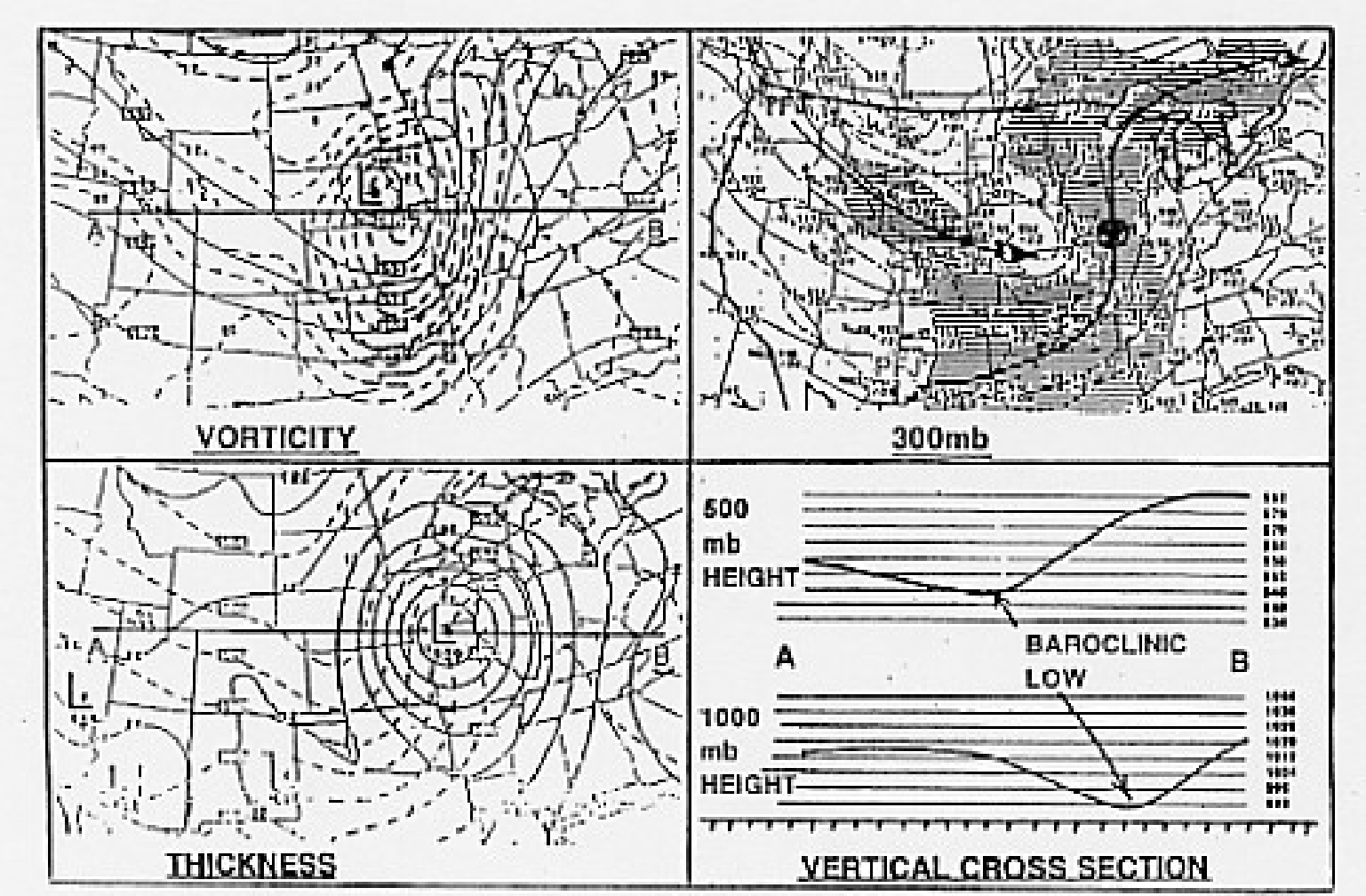
Baroclinic Systems

- A state of atmosphere where contours and isotherms are out of phase
- Promotes temperature advection which generates vertical motion patterns, surface pressure changes, and height changes on upper-level isobaric surfaces (i.e., 850, 700, 500, 300 mb height changes).

Baroclinic Systems

- **Baroclinic Lows**
  - Exists in a region of strong thermal contrast
  - Axis tilts with height
    - Tilts with height to a major short-wave trough aloft
    - Stacks up toward cold air
    - Tilted stack of system causes the wind to change direction with height

Baroclinic Low

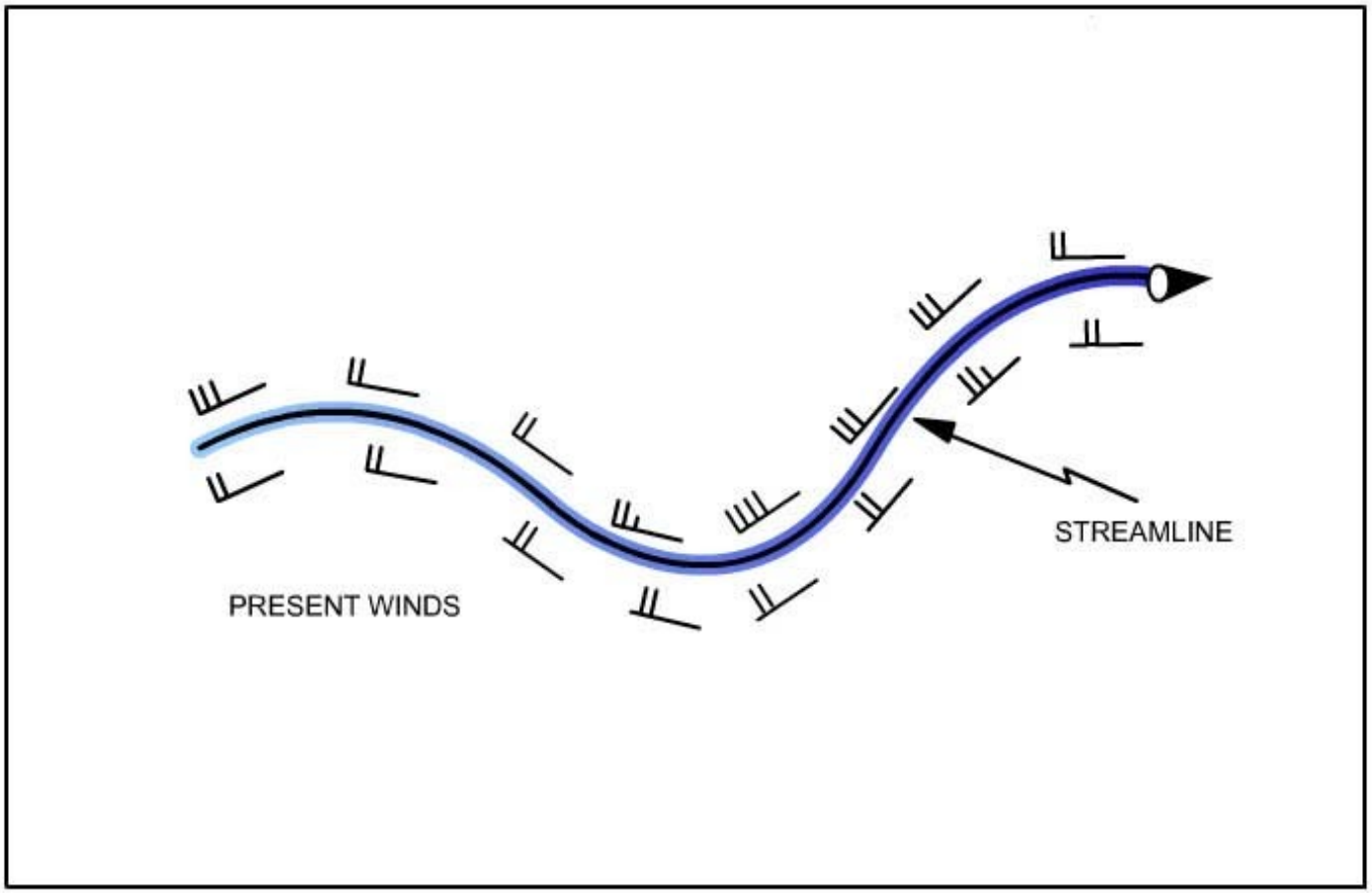


Baroclinic Systems

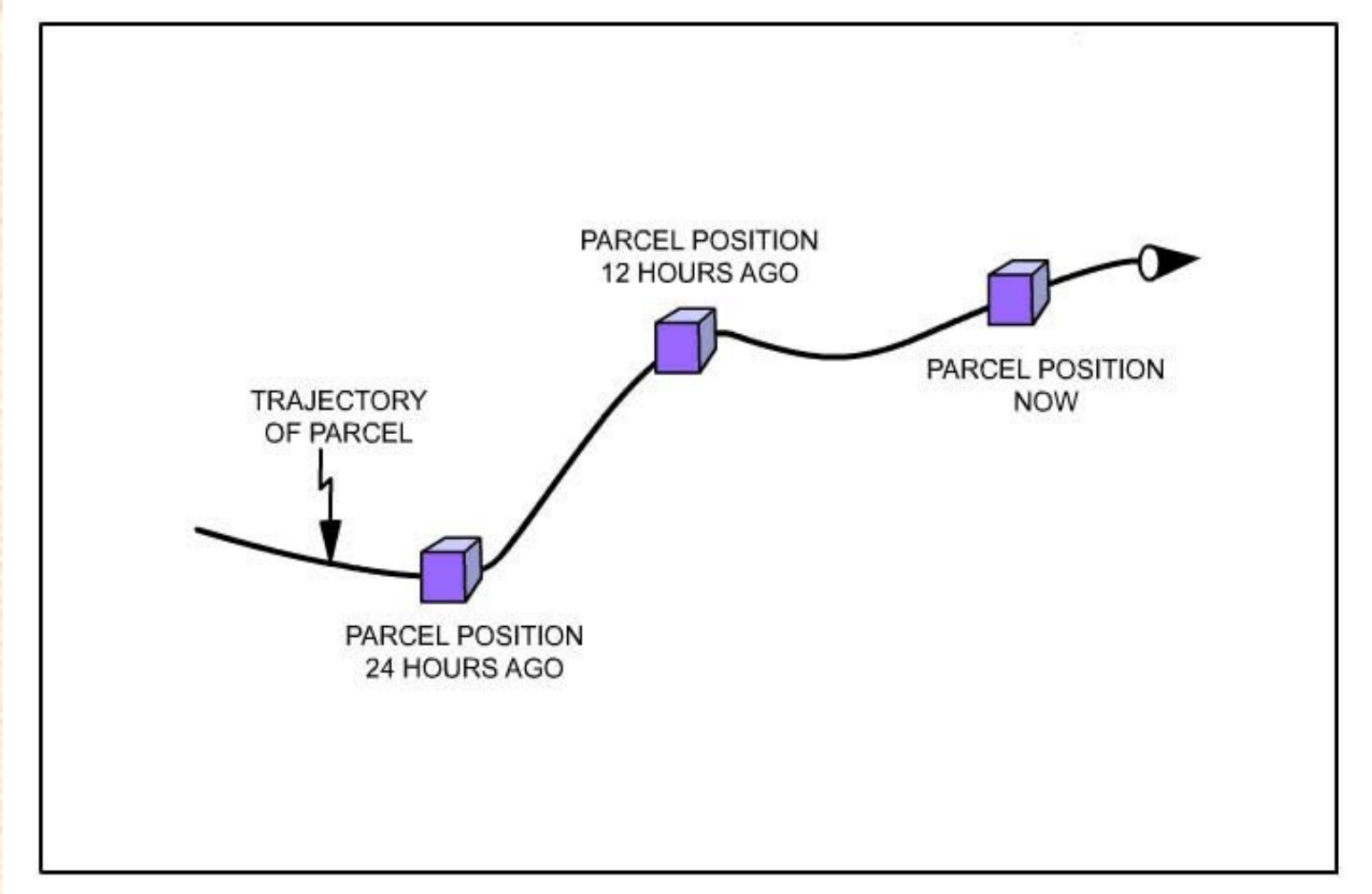
– Wind Flow Terminology

- Streamline - line depicting the direction all air parcels are moving at any instant in time
- Trajectory - path taken by one air parcel as it moves through space over time

Streamlines



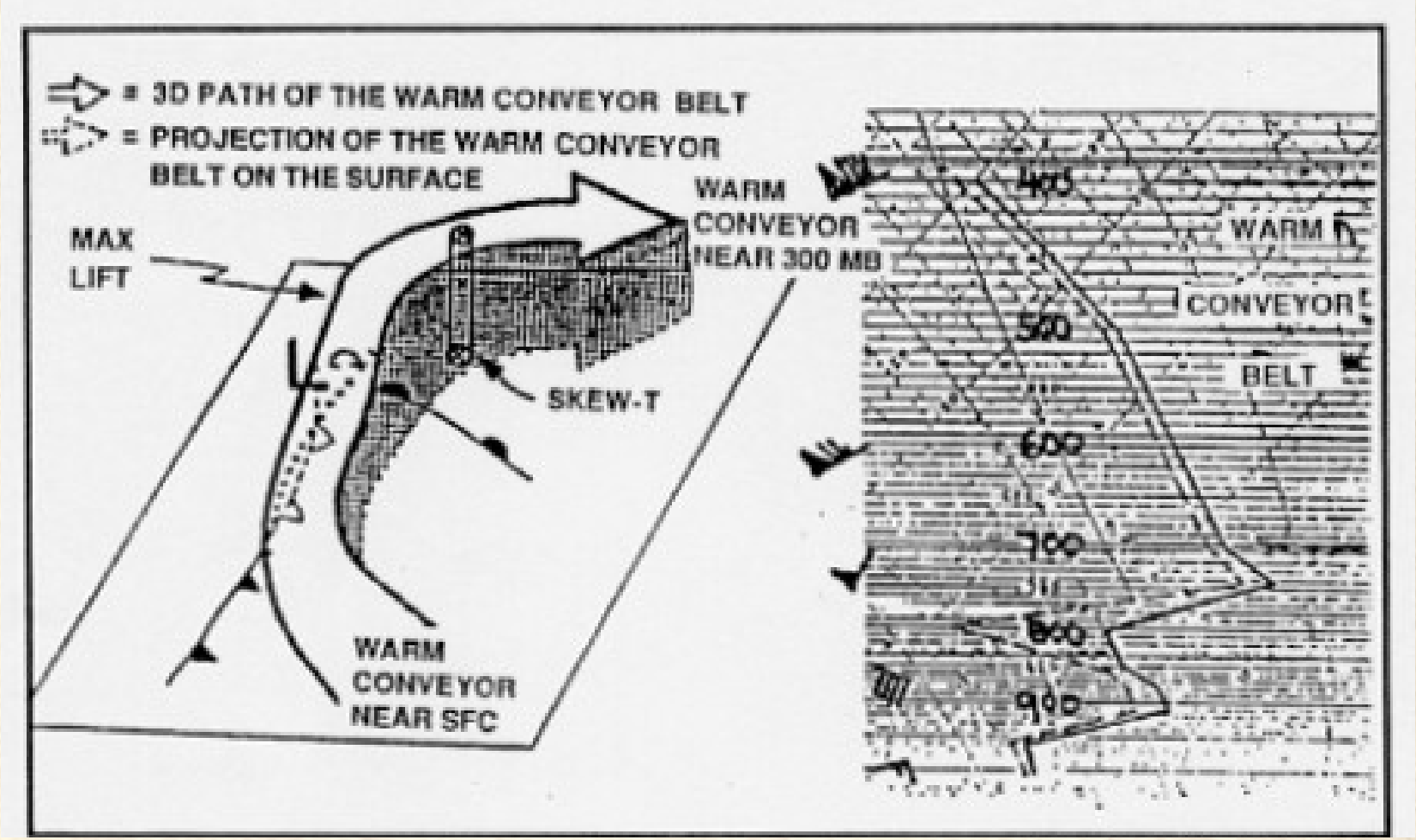
Trajectories

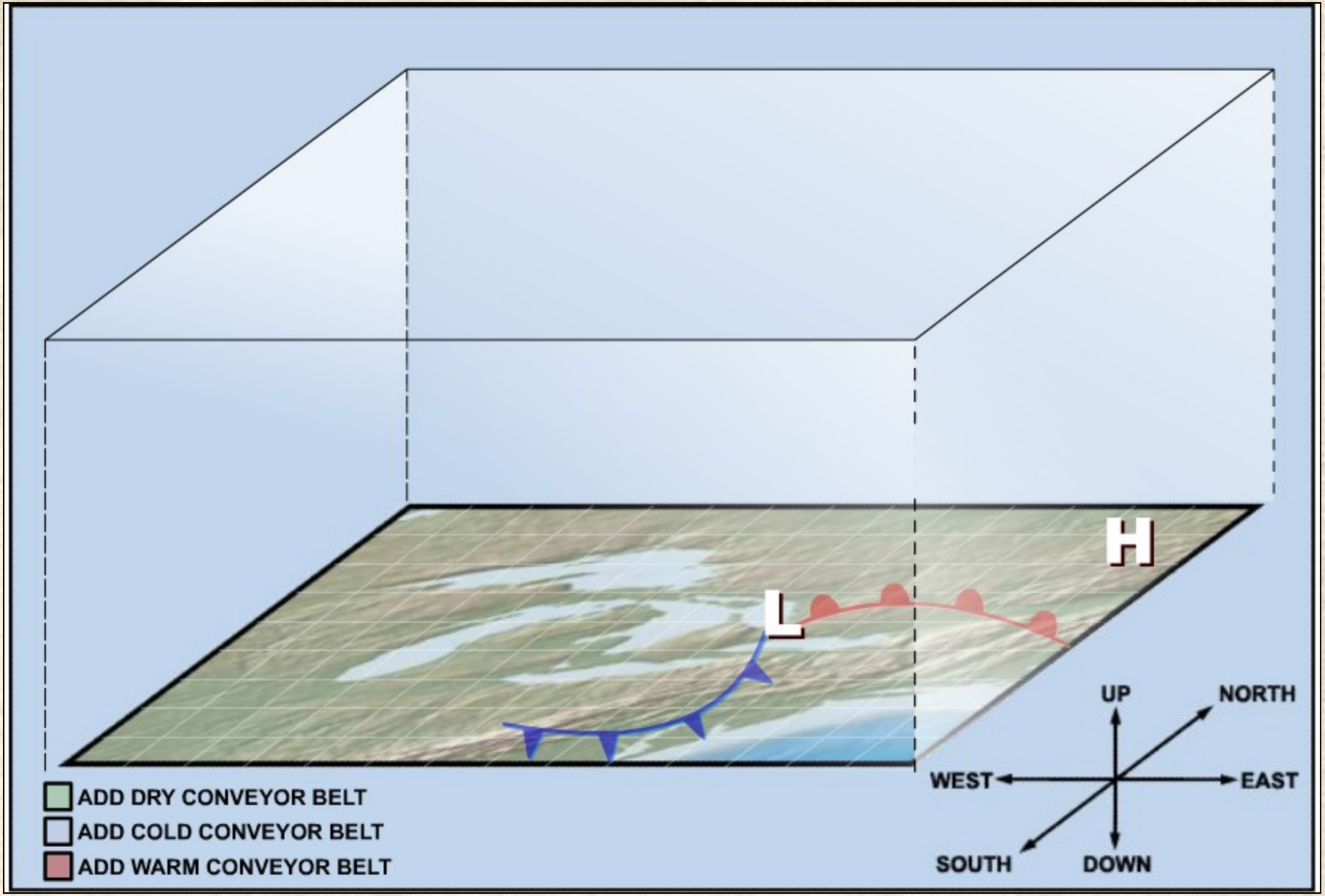


Baroclinic Systems

- Streamlines through baroclinic lows
  - Warm Conveyor Belt (WCB*)*
    - Streamlines originating at the low levels in moist tropical (i.e., mT) air mass, are located equatorward of surface low
    - Flows poleward, ascends and turns anticyclonically at jet stream level
    - In a stable environment, the strongest ascent occurs near surface low. In conditionally unstable air, strongest ascent may occur further equatorward in convection within the warm sector of the cyclone.
    - Baroclinic zone cirrus forms in northern portion

Warm Conveyor Belt

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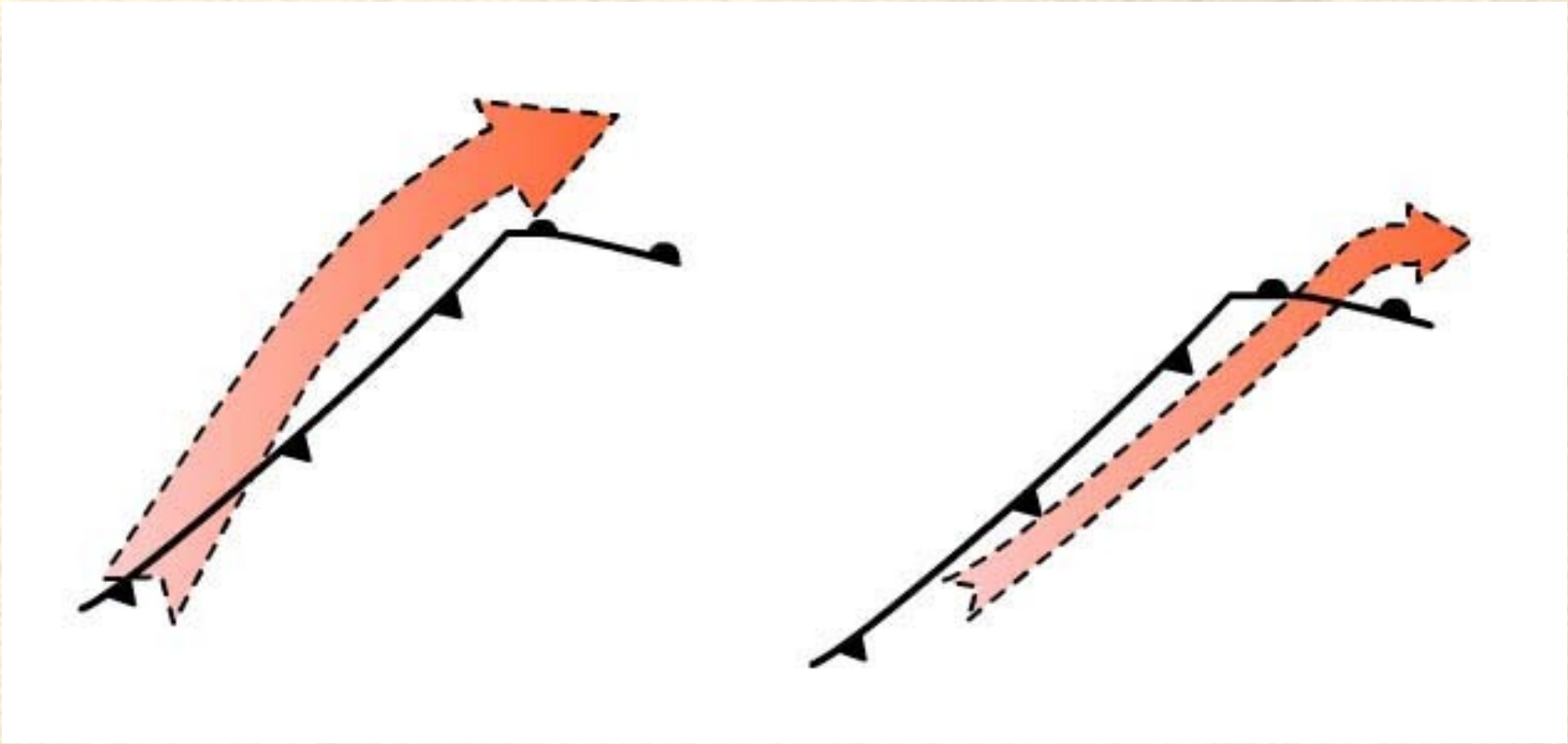
L
UP
NORTH
WEST
EAST
SOUTH
DOWN
ADD DRY CONVEYOR BELT
ADD COLD CONVEYOR BELT
ADD WARM CONVEYOR BELT

Baroclinic Systems

- Flows northward ahead of cold front in one of two configurations
  - Associated with slow-moving active cold front
    - » Ascends frontal surface
    - » Referred to as rearward sloping ascent
    - » Generally associated with a positively-tilted upper-level trough.

Rearward and Forward Sloping Ascent



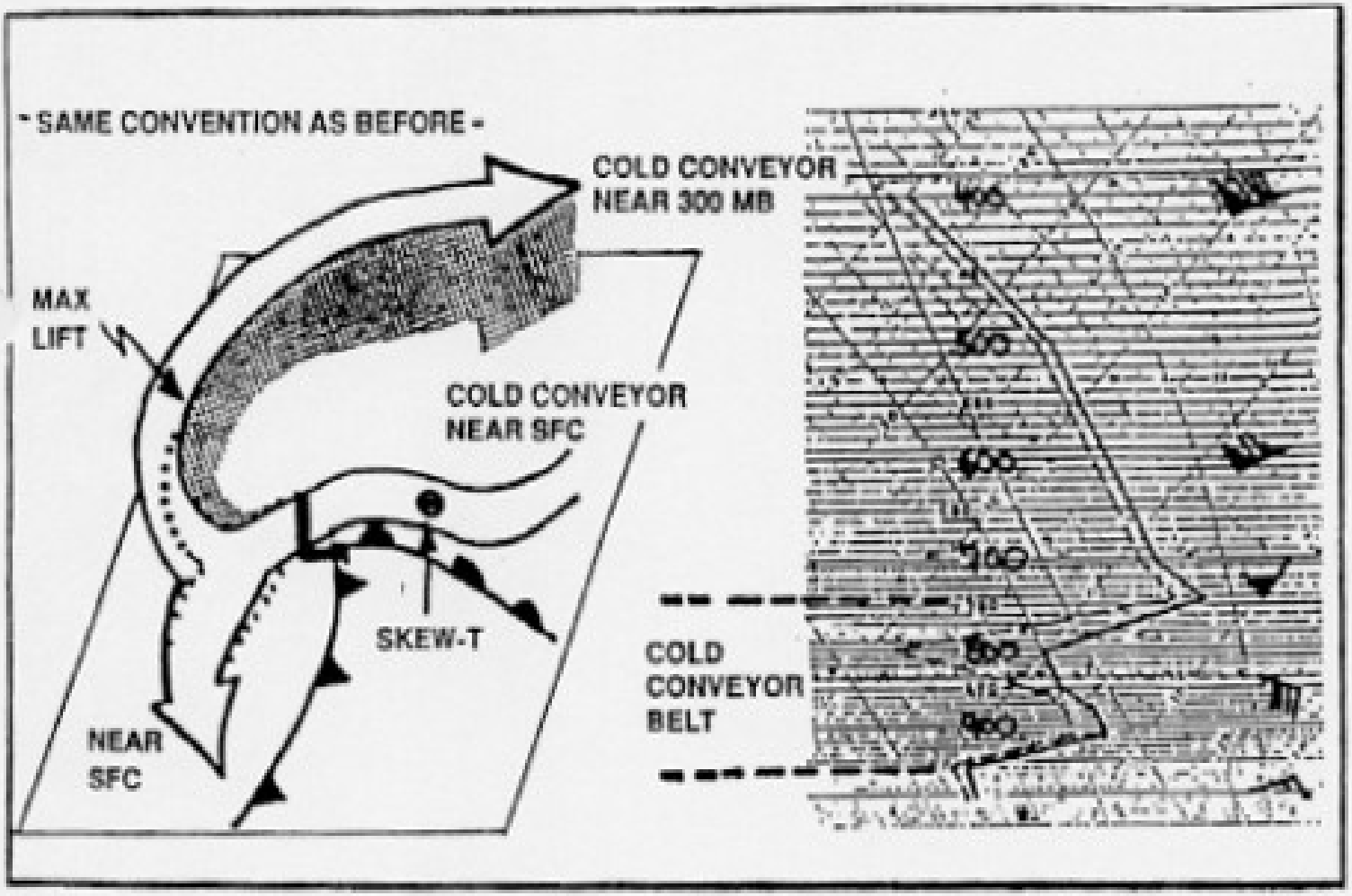
Baroclinic Systems

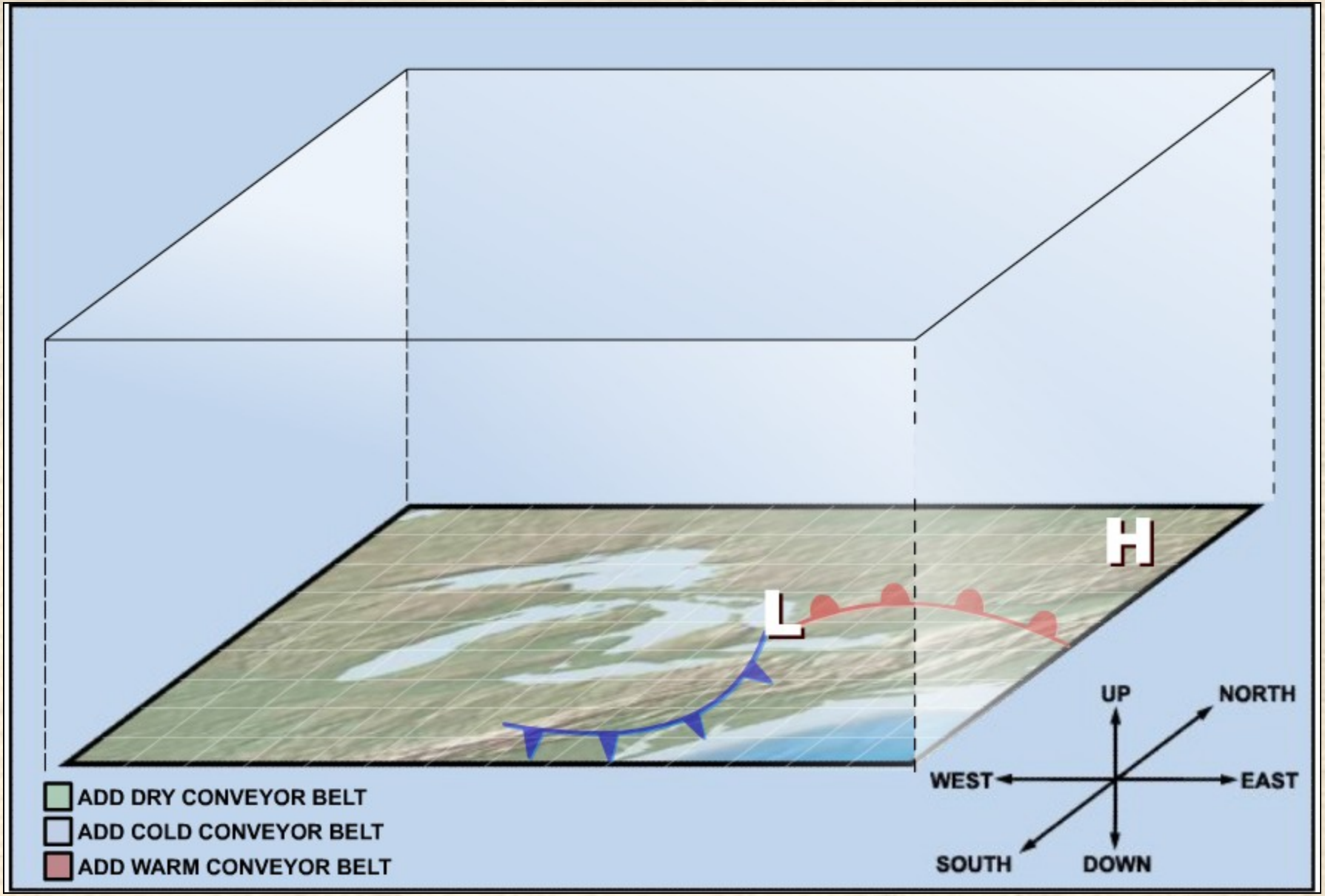
- Associated with fast-moving active cold front
  - » Will not rise over frontal surface
  - » Referred to as forward sloping ascent
  - » Generally associated with a neutrally- or negatively-tilted upper-level trough.

Baroclinic Systems

- Cold Conveyor Belt (CCB)
  - Originates at low levels, in cool air poleward of warm front/east of low center
  - Flows westward beneath WCB
  - Associated with subsidence well ahead of low center
  - Ascends rapidly west of low
    - » Widespread cloudiness and precipitation associated with rising “cold” air
    - » Cloudiness composes "head" comma cloud system

CCB

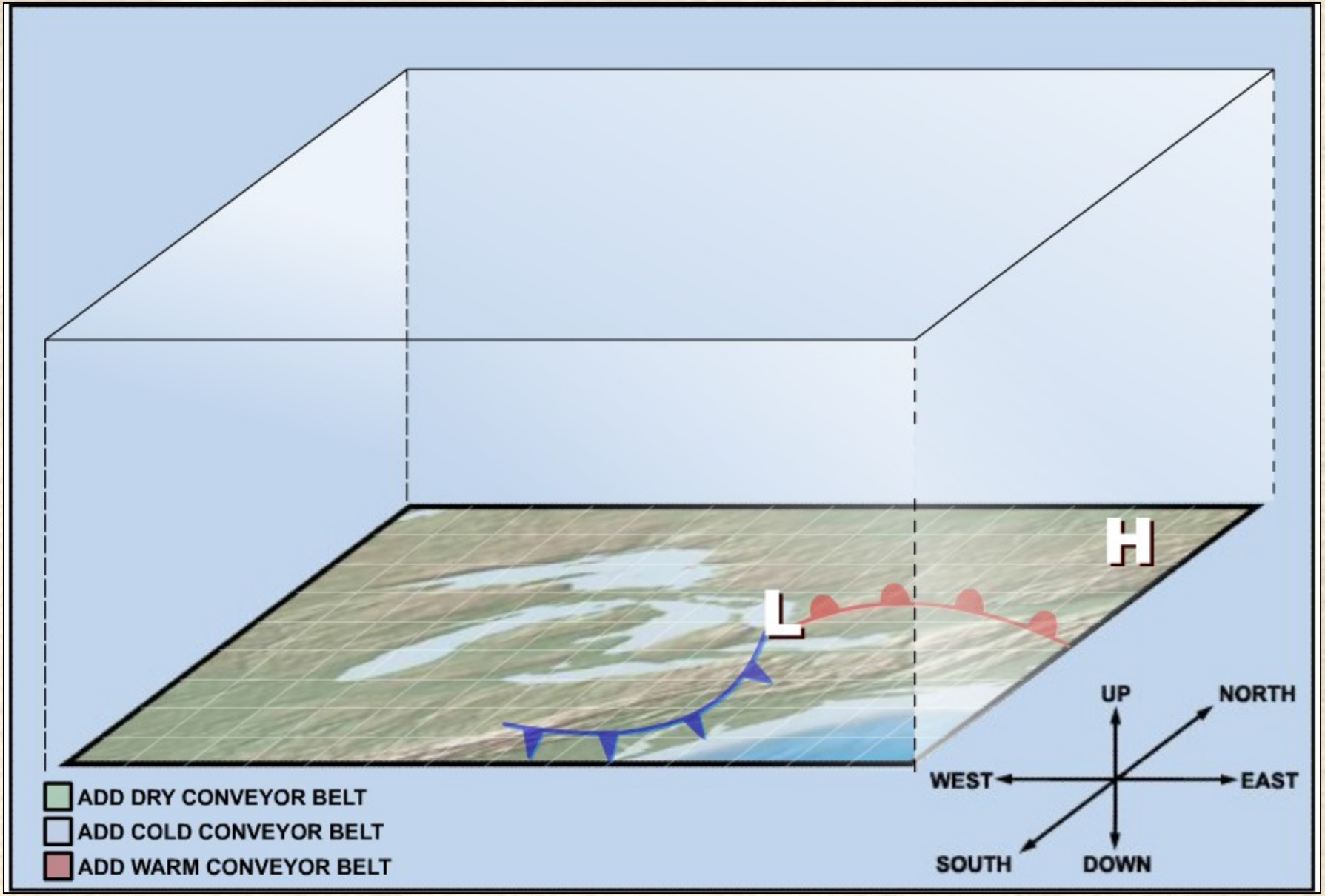

- SAME CONVENTION AS BEFORE -
COLD CONVEYOR
NEAR 300 MB
MAX
LIFT
COLD CONVEYOR
NEAR SFC
SKEW-T
NEAR
SFC
COLD
CONVEYOR
BELT


H
L
ADD DRY CONVEYOR BELT
ADD COLD CONVEYOR BELT
ADD WARM CONVEYOR BELT
UP
NORTH
WEST
EAST
SOUTH
DOWN

Baroclinic Systems

- West of the low, it may follow one of two paths
  - Continues to rise, and turn sharply anticyclonically
    - » Widespread cloudiness and precipitation

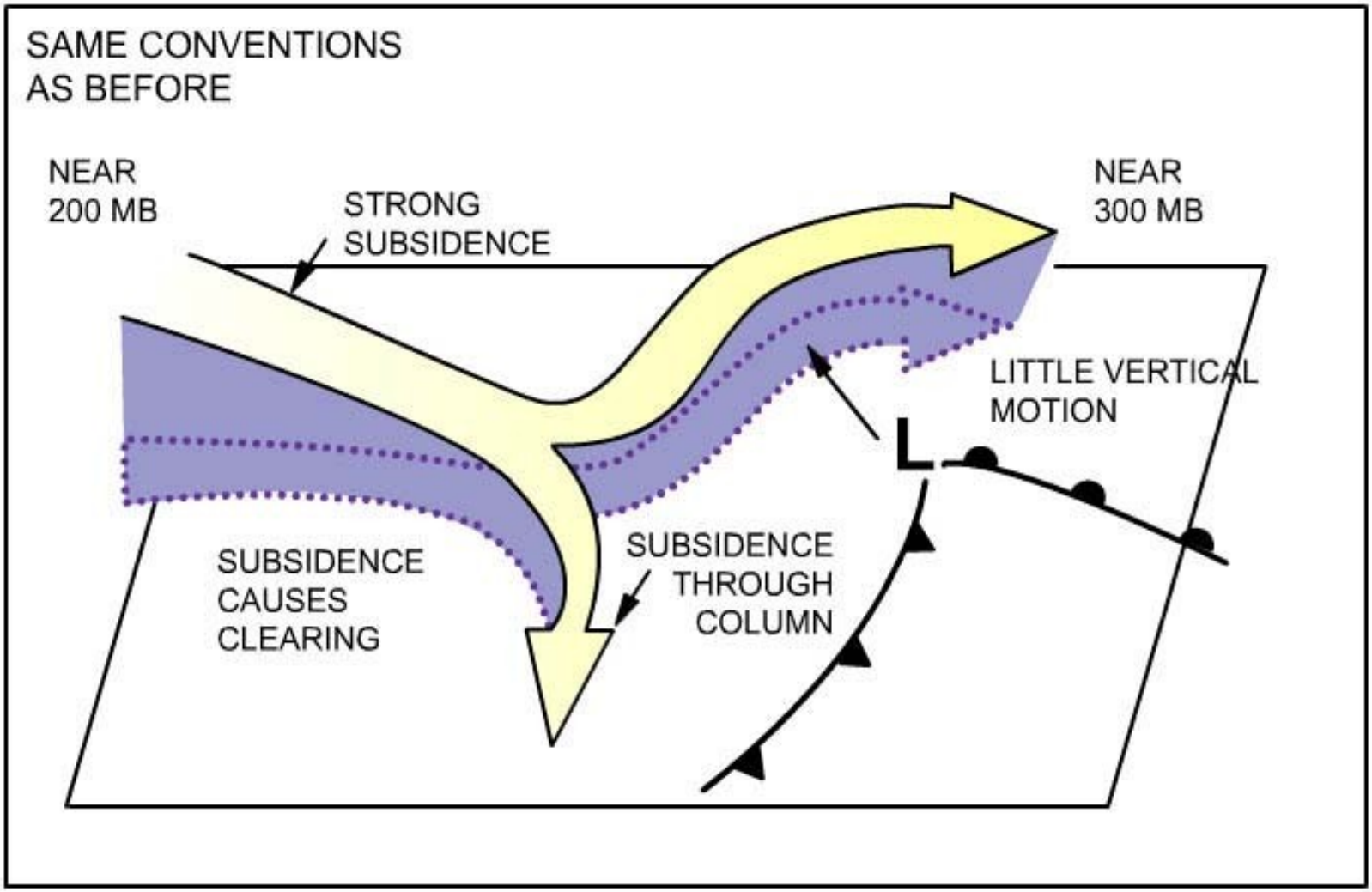
      Location of heavy snow band in cyclone (if thermal conditions favor frozen precipitation there).
    - » Composed of Deformation Zone Cirrus
  - Remains in low levels, turning cyclonically, descending well west of the low center
    - » Responsible for CAA behind low
    - » Cold air stratocumulus


H
L
ADD DRY CONVEYOR BELT
ADD COLD CONVEYOR BELT
ADD WARM CONVEYOR BELT
UP
NORTH
WEST
EAST
SOUTH
DOWN

Baroclinic Systems

- Dry-Air Conveyor Belt (DCB)
  - Streamlines originating at upper levels upstream from the major short-wave trough supporting the low
  - Flows eastward
  - When approaches short-wave trough, undergoes strong subsidence and drying

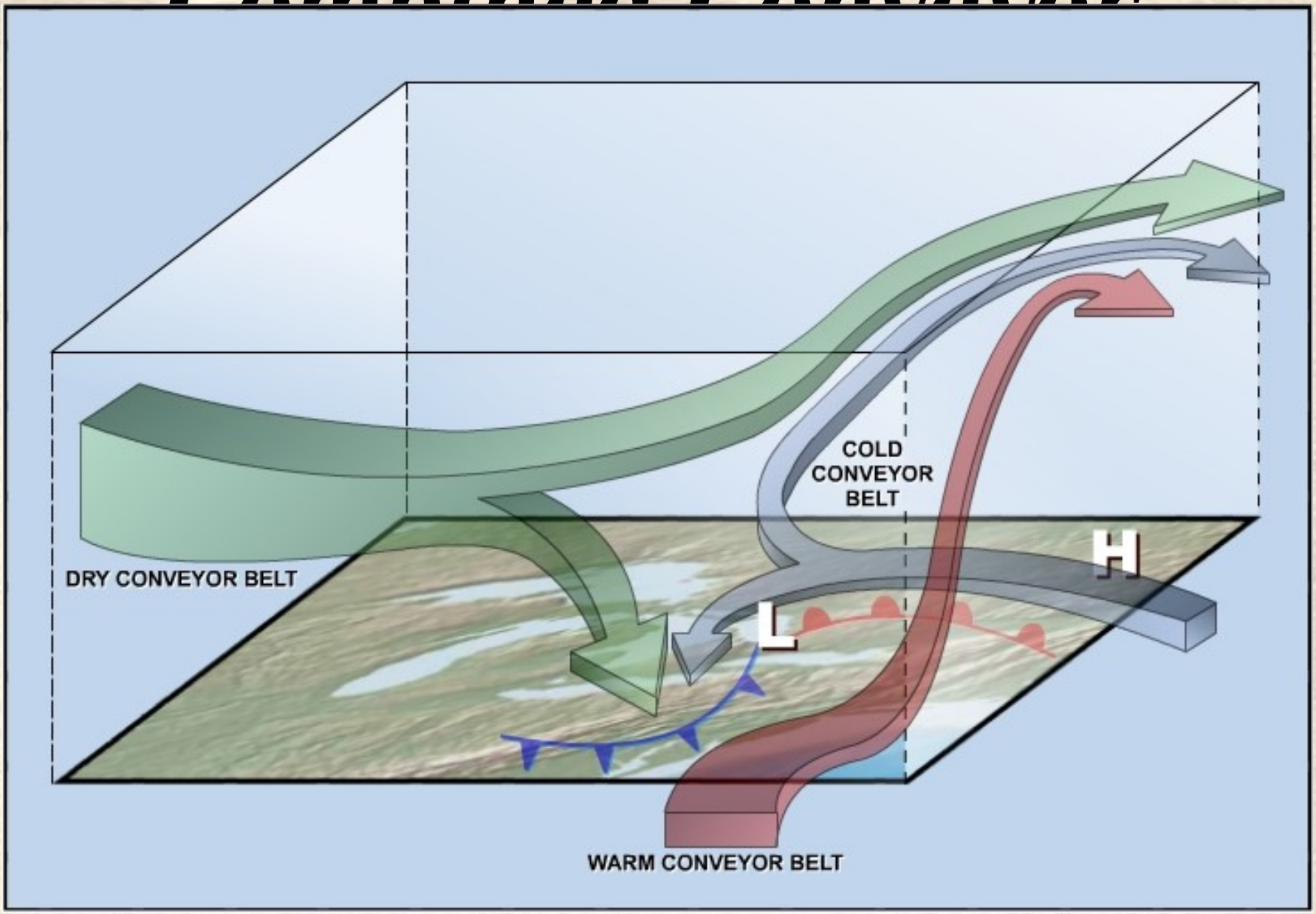
Dry Conveyor Belt



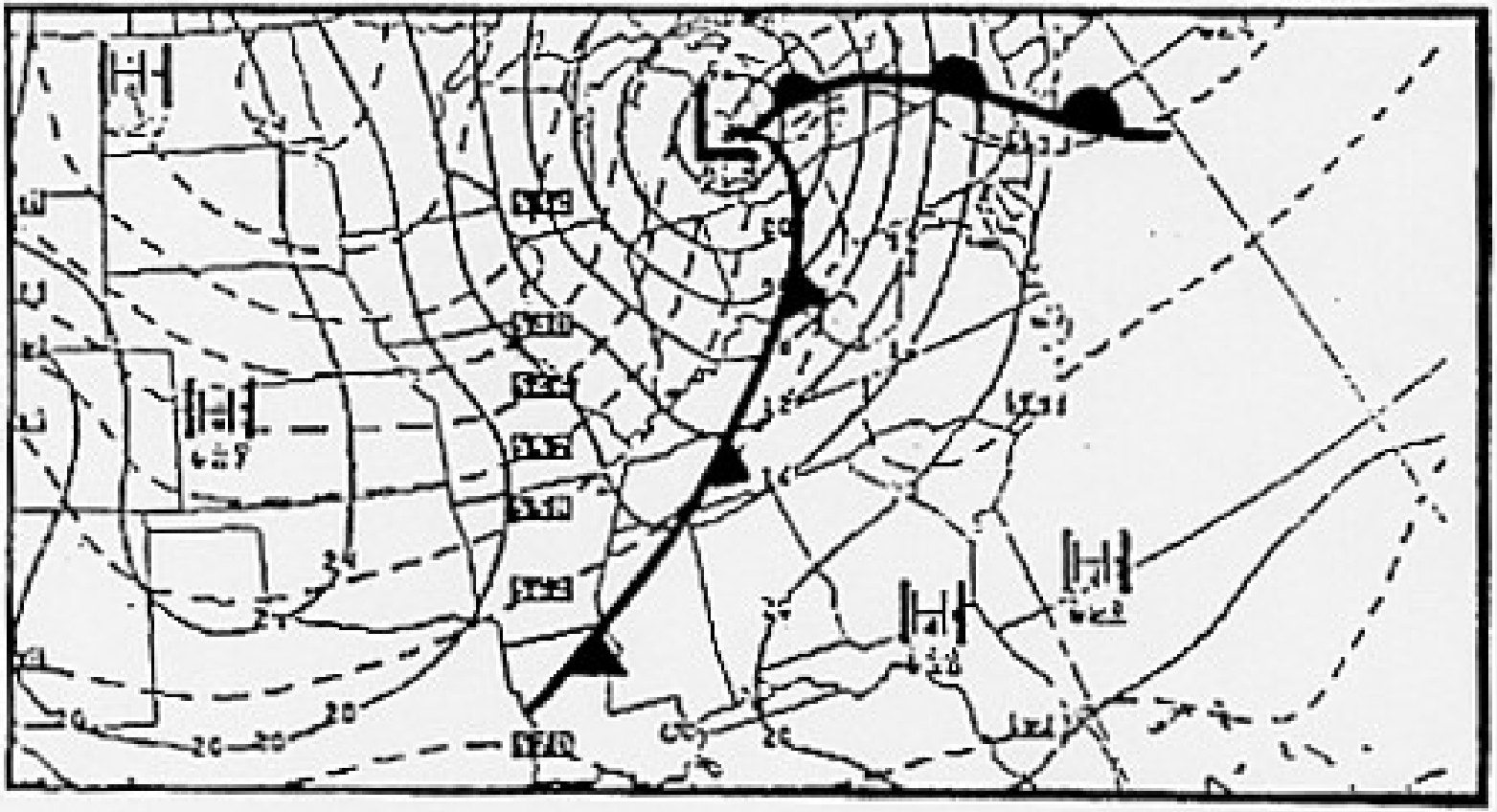
Baroclinic Systems

- Splits into two branches near low
  - » One remains in the upper levels, turning first cyclonically then anticyclonically, toward the northwest of WCB
  - » Causes smooth high cloud border north
  - » Other descends turning anticyclonically to low levels well behind low
  - » Causes smooth edge on western edge of cold air SC

Combined Conveyor



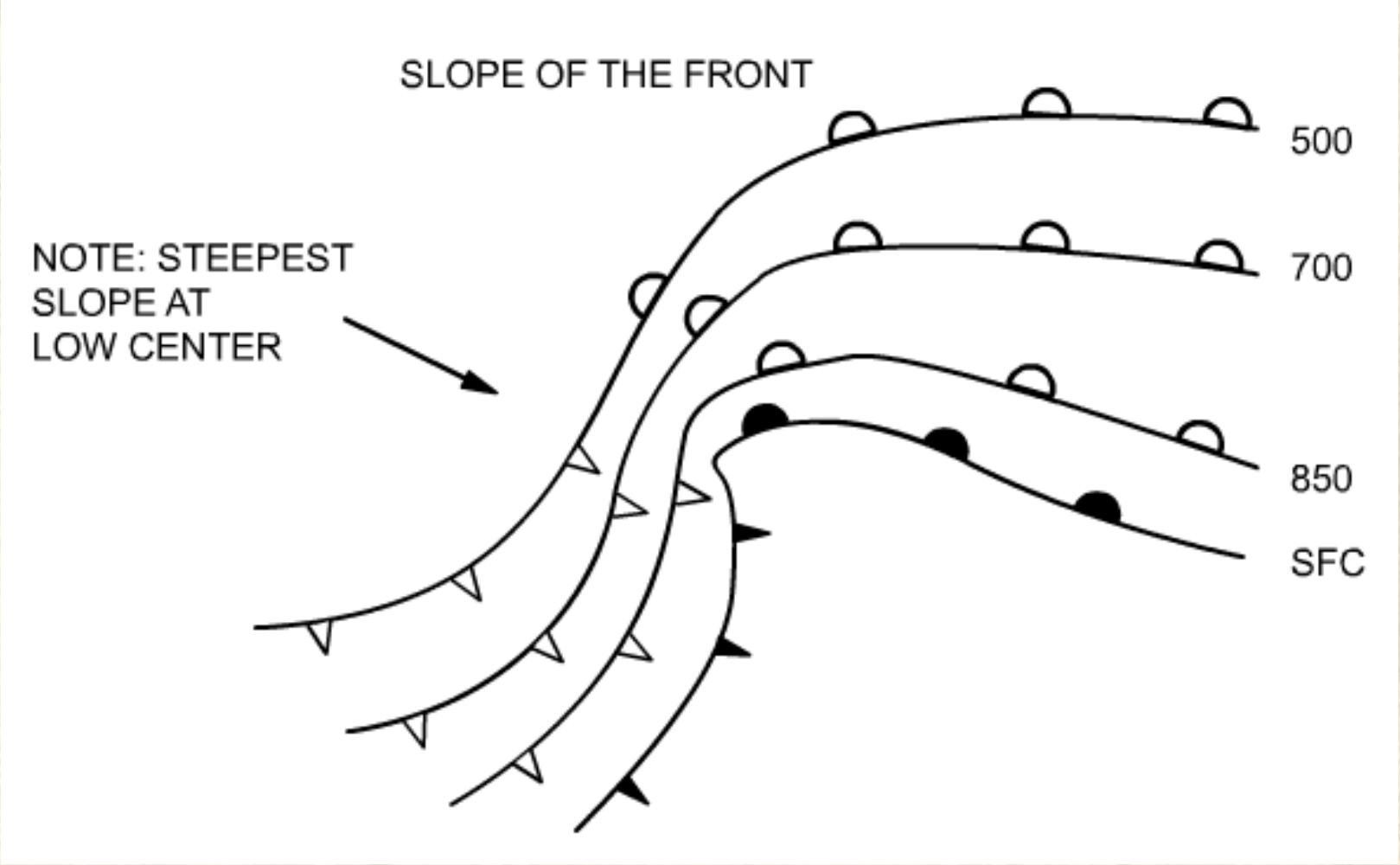
Baroclinic Low Along A Frontal System



Baroclinic Systems

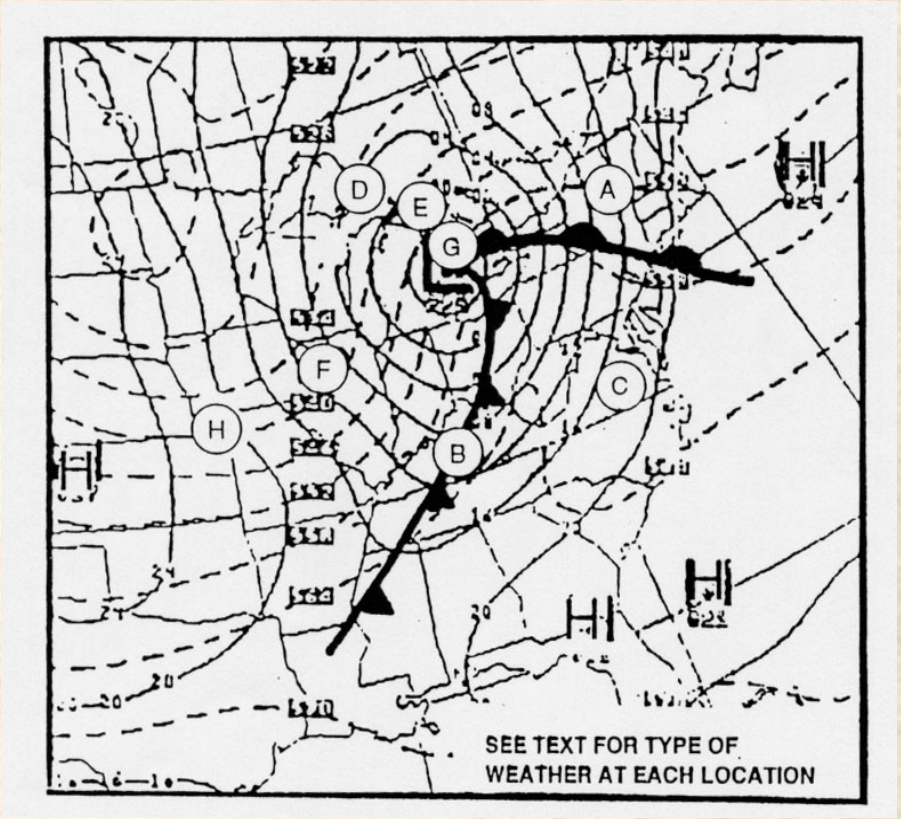
- Baroclinic lows associated with strong thermal contrast; forms along frontal system
- Flow around low creates thermal advection
- PFJ defined by thickness packing behind cold front and ahead of warm front

Slope Of The Frontal Surface At The Center Of The Baroclinic Low

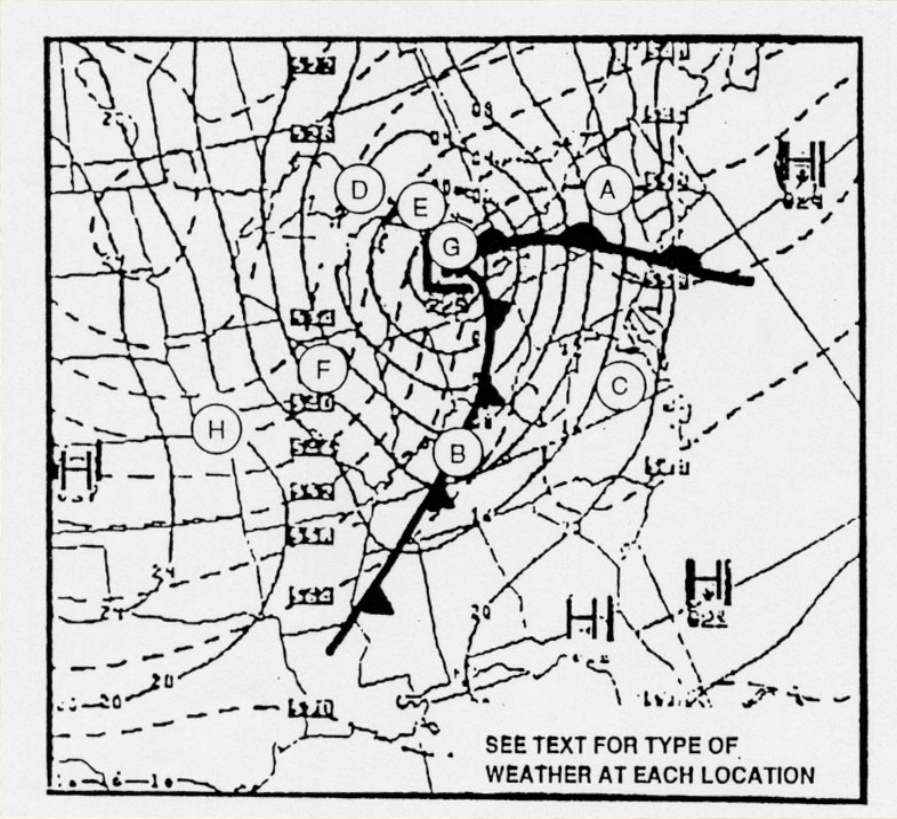


Baroclinic Systems

- Weather associated with baroclinic low
  - Point A: Warm advection “overrunning” or “isentropic upglide” associated with warm front.
  - Point B: Depends on type cold front (active or inactive).

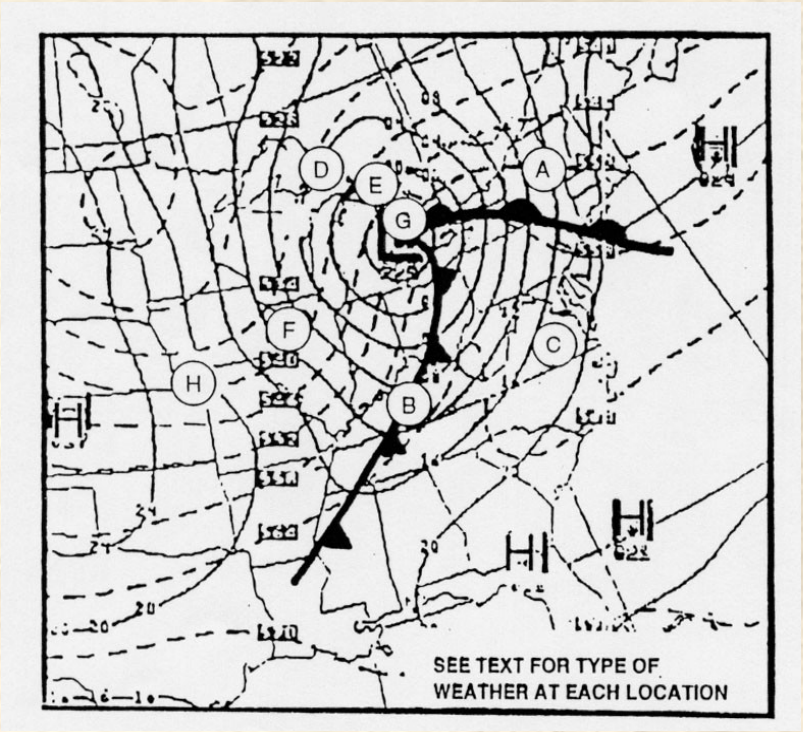


- Point C: Vary depending on stability
  - Warm over cold - cold temperatures and very stable, advection fog and stratus often occur
  - If surface warm and further heated by sun - warm temperatures and instability is likely with isolated thunderstorms



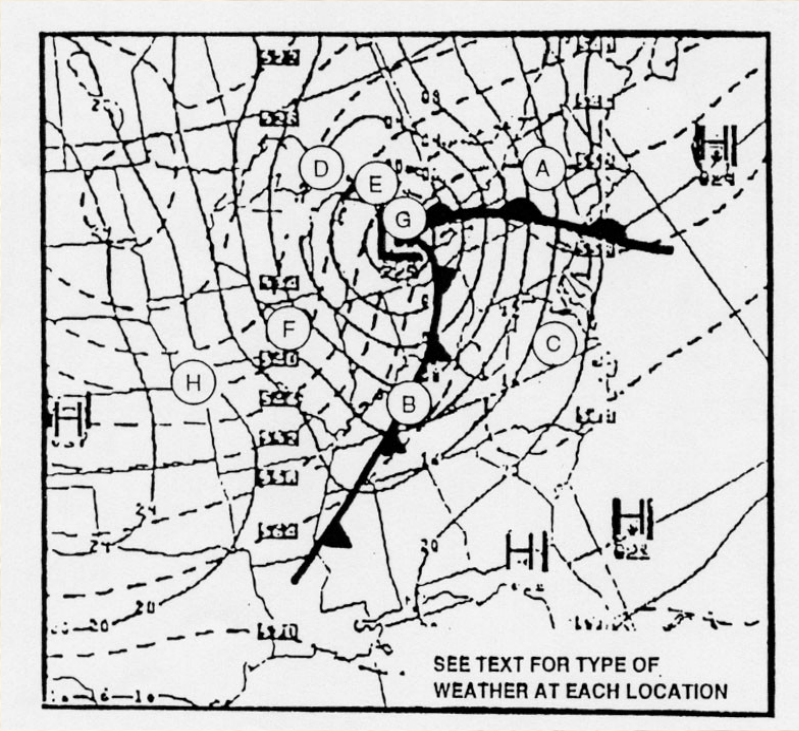
Baroclinic Systems

- Point D: Divergence aloft within upper-level deformation zone causes precipitation
- Point E: Divergence aloft /WAA overlap
  - CCB ascending sharply in this region
  - Typically has heavy precipitation and is often where the cyclone's heavy snow band develops (if any).

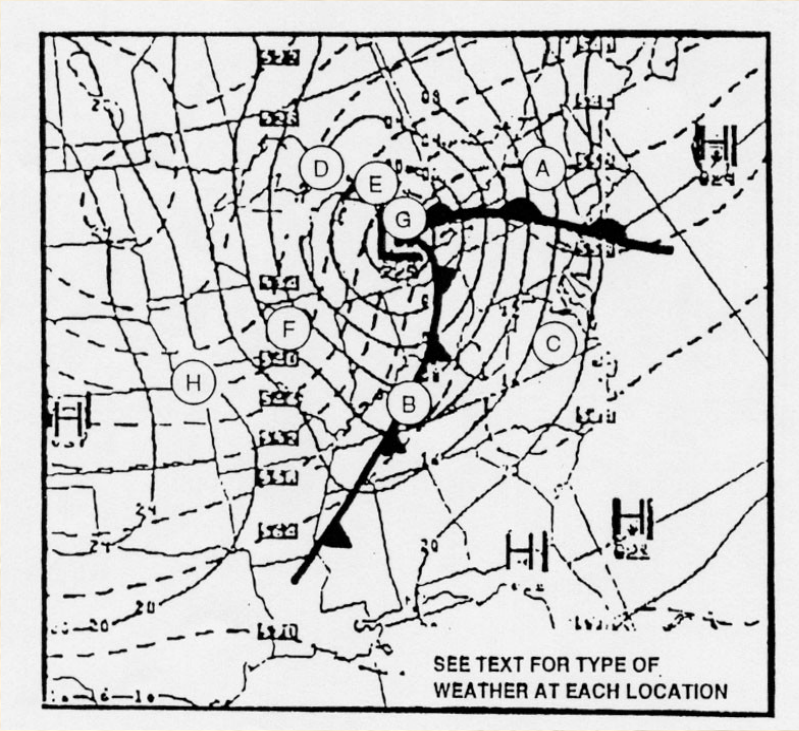


Baroclinic Systems

- Point F: Low cloudiness left behind is sometimes called "backwash" or "wrap-around"
  - Caused by BLC within cyclonically curved flow surrounding low (Astling, 1976)
  - Residual low-level moisture with portion of cold conveyor belt wrapping cyclonically around west side of low (CCB initially gained moisture from precipitation falling from WCB poleward of warm front)



- Point G: Light precipitation and low ceilings prevail
- Point H: Fair weather associated with dry conveyor belt subsidence caused by convergence aloft, cold-air advection, and surface divergence within anticyclonic flow.



Baroclinic Systems

- Generally form along frontal systems downstream from long-wave trough where the gradient wind relation favors upper-level divergence.
  - Moves northeast
  - Attain peak intensity before reaching downstream long-wave ridge position
  - More intense systems may occlude and become more vertically stacked with the upper-level trough.

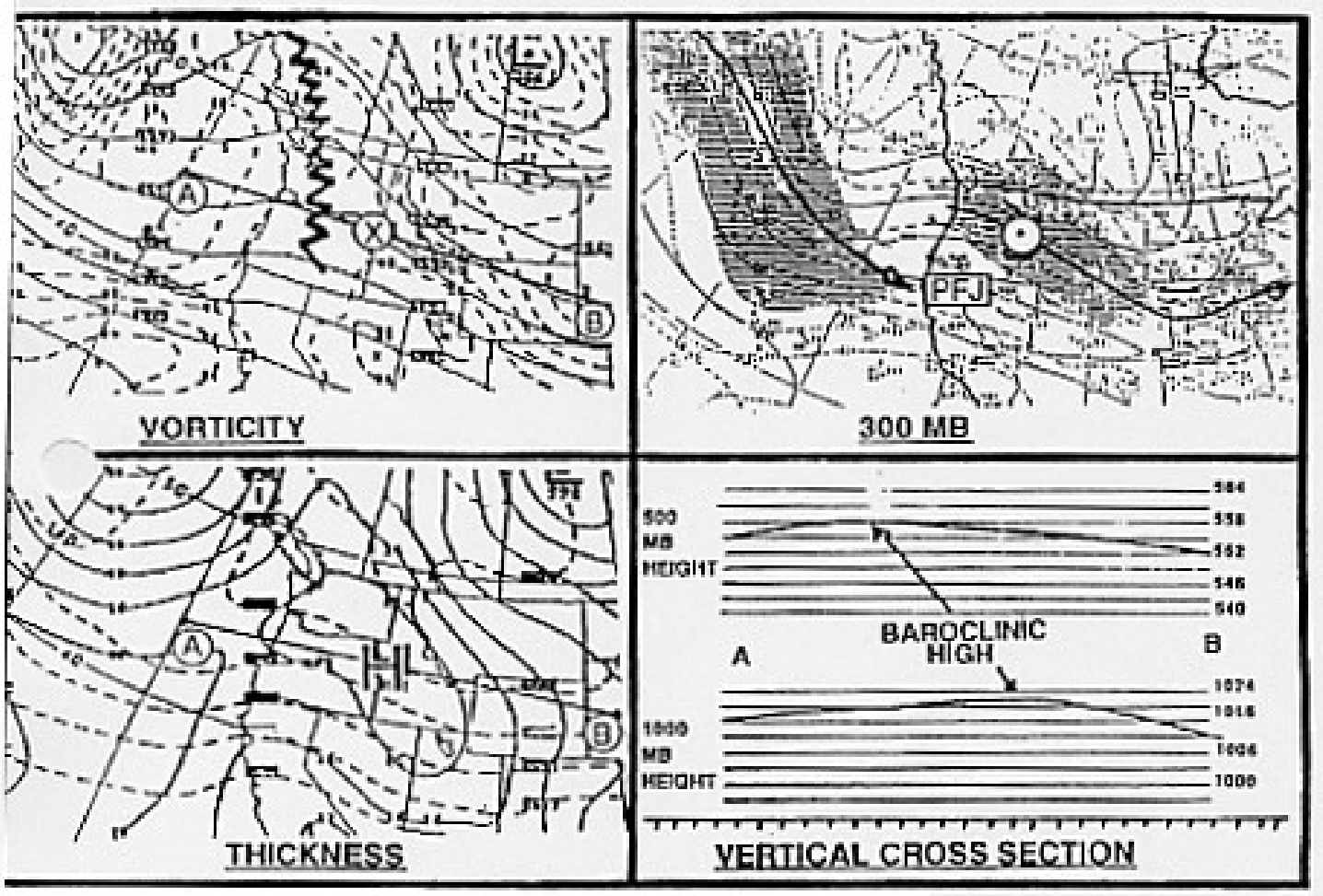
Baroclinic Systems

- **Baroclinic Highs**
  - Exist in region of strong thermal contrast
  - Axis tilts with height
    - Pressure (height) system tilts with height to upper-level major short-wave ridge
    - System stacks up toward the warm air
  - Tilt causes wind to change direction with height, producing thermal advection patterns.

Baroclinic Systems

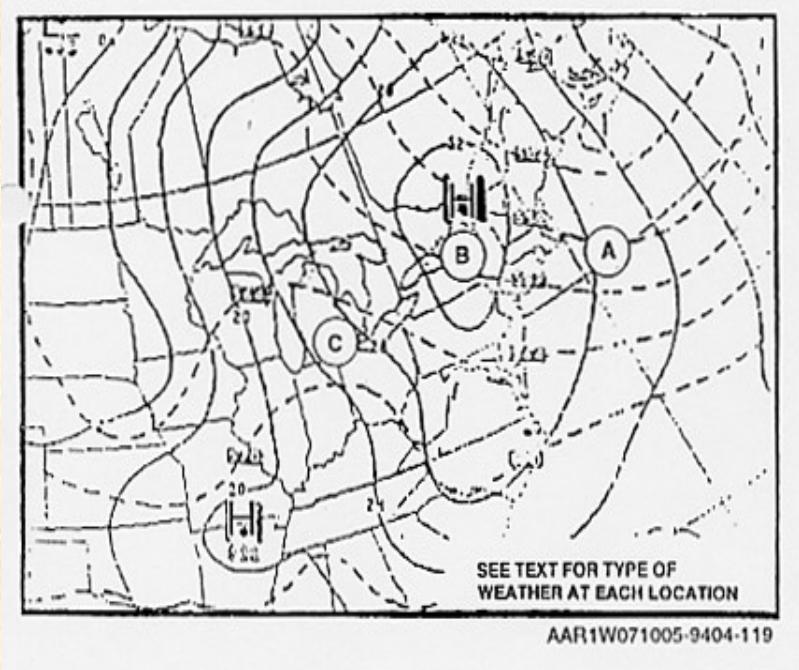
- Does not form along front
  - Front cannot form or persist through a high or a region of well-defined surface ridging
  - Convergence aloft, hence frontolysis occurs
  - Anticyclonic flow in boundary layer leads to divergence and frontolysis
- High located in thickness ribbon, PFJ located above

Baroclinic High



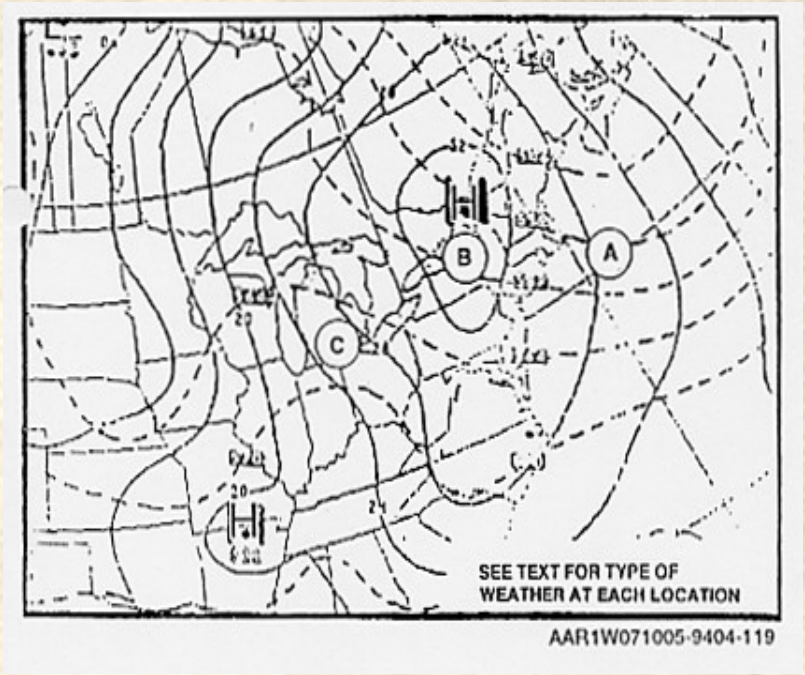
Baroclinic Systems

- Weather varies
  - Point A: Convergence aloft and cold advection producing subsidence and fair weather
  - Point B: Clear skies and light winds promote strong radiational cooling of surface at night with possible heavy dew, frost or radiation fog beneath strong radiation inversion.



Baroclinic Systems

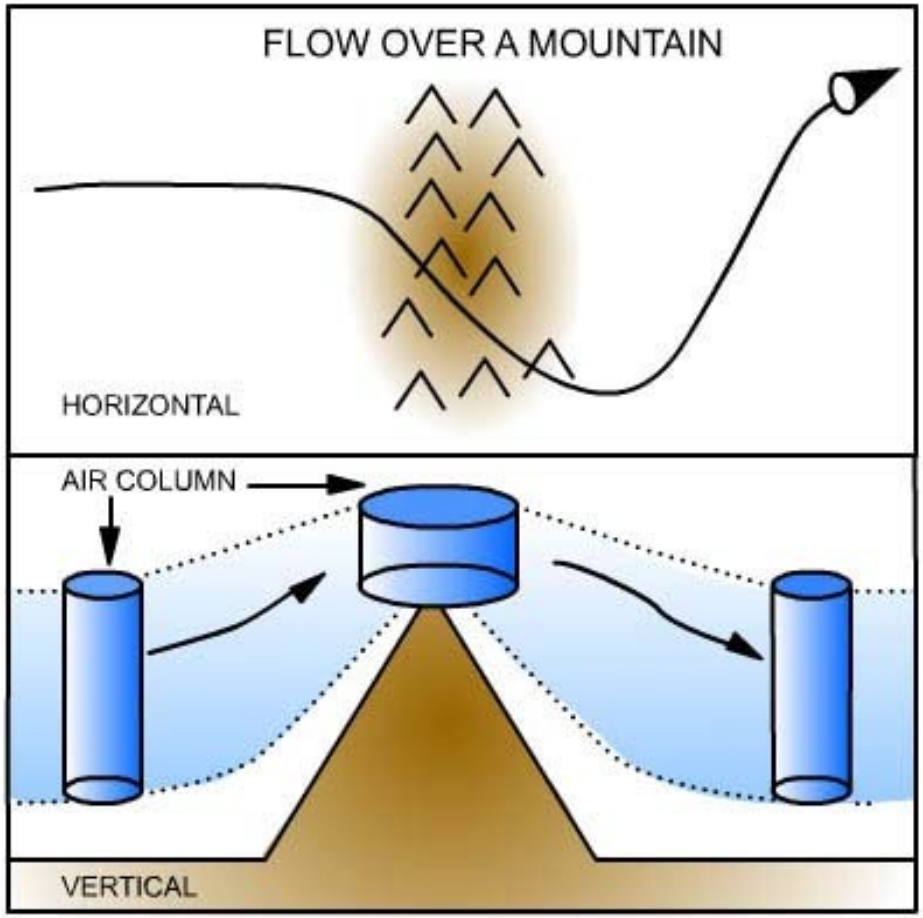
- Point C: Warm advection favors upward vertical motion and increasing clouds and possible precipitation
- Forms downstream from long-wave ridges where gradient wind relationship favors upper-level convergence and subsidence.



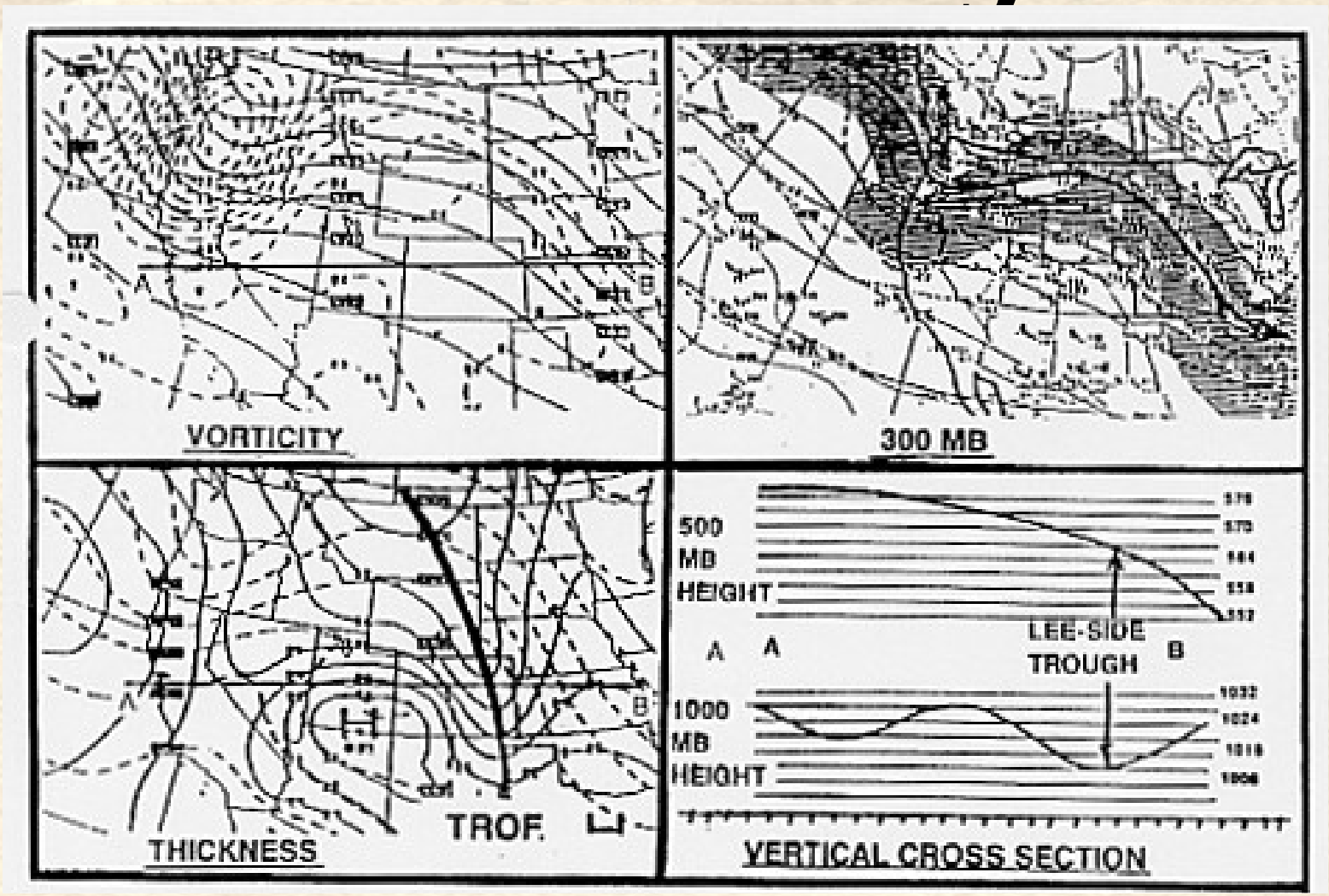
Troughs

- **Lee-side trough and low**
  - Develops on the lee of a north-south mountain range within westerly (i.e., west to east) mid-and upper-tropospheric flow
    - If forcing is strong enough, a low will form
    - Warmest air is at the center
      - It is associated with dry-adiabatic lapse rates (i.e., neutral stability) due to strong dry-adiabatic subsidence east of the mountains.
      - It is not a warm barotropic low but a shallow orographically-induced trough or low.

Flow Over A Mountain Barrier



Lee Side Trough



Troughs

- Troughing strongest in low levels
  - It can have troughing at up to 700 mb, but is rarely seen above 700 mb.
  - Upper level ridging will be present

A lee-side trough first starts to form when the upper-tropospheric ridge axis first passes the north-south mountain range (i.e., lee-side troughing development is coincident with passage of the upper-level ridge axis. Thus, a lee-side trough or low develops well ahead of any approaching upper-level baroclinic trough.

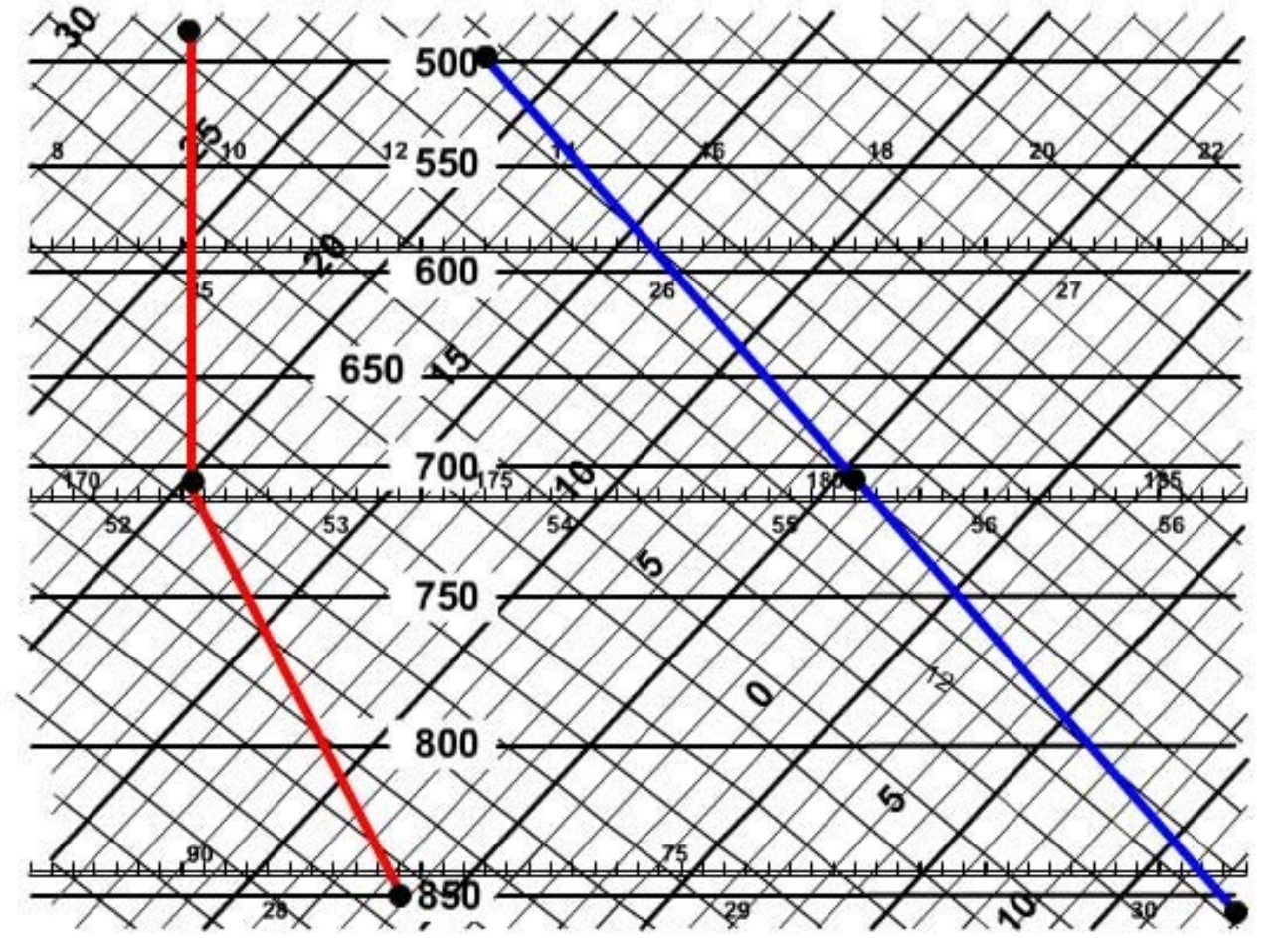
Troughs

- Wind flow varies with height
  - Upper- and mid-level winds will have a strong westerly component
  - There is strong cyclonic turning in low levels associated with the lee-side trough itself.
- It is not associated with fronts, but is often associated with a dry line.
- It is not necessary for the lee-side trough to form beneath jet

Troughs

- Lee-side troughs form as result of the conservation of potential vorticity within an air column (see Dynamics I).
  - Strong westerly winds aloft force air to ascend then descend the mountain range
  - Air ascends windward side of mountain range turning anticyclonically
  - Descending air will turn cyclonically
    - » A trough is induced in cyclonic turning
    - » Adiabatic warming causes pressure to fall

Skew-T Through a Lee-Side Trough



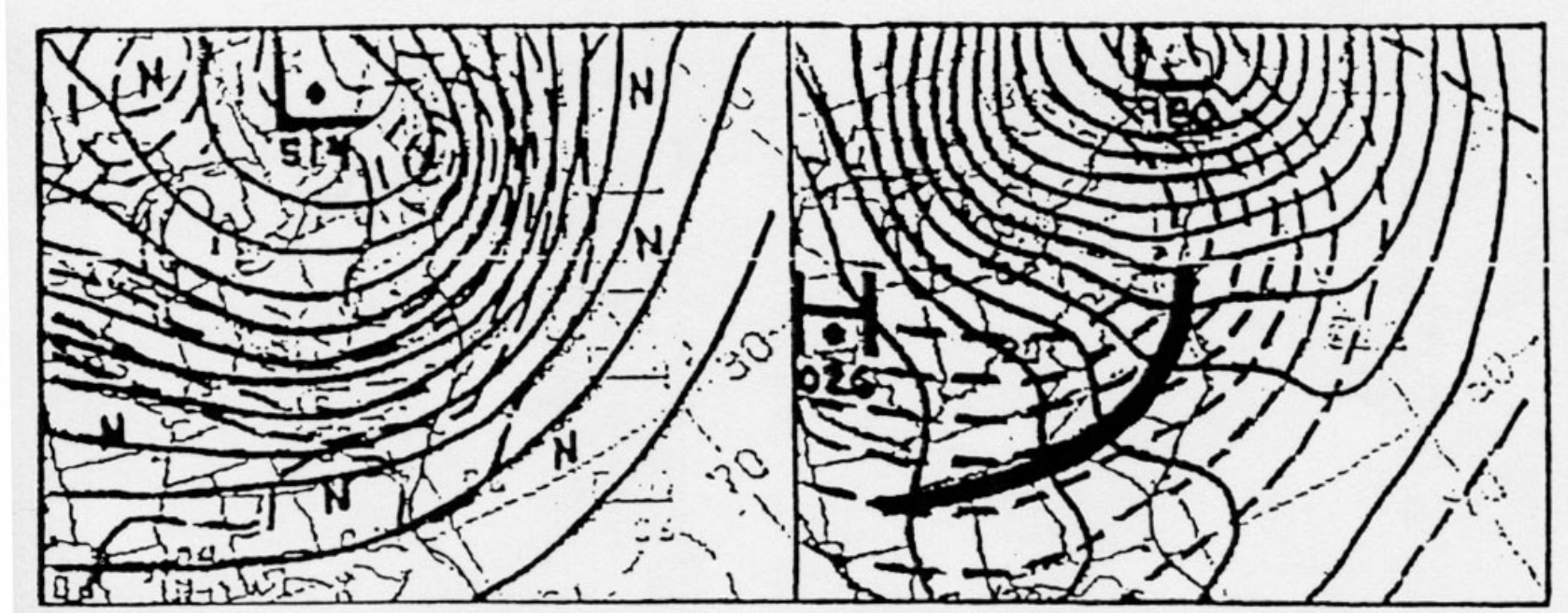
Troughs

- Associated weather includes windy, warm, dry, possible mountain wave clouds
  - Adiabatic warming heats air
  - Precipitation and clouds occur on windward side
  - It is dry on the lee-side
  - Strong westerly winds mix downward. In some cases of lee-side trough development, severe downslope winds occur. These events are known as “Chinooks” east of the Rockies.
- Lee-side troughs are common on east side of Rockies

Troughs

– Cyclone development on east-west mountains may occur, due to other reasons.

Post Frontal Trough



Troughs

- **Post frontal troughs**
  - This typically forms in advancing cold air mass
  - They are strongest at surface and weaken with height
    - Temperature difference between cold air and surface determines how high the trough extends
    - To be reflected at 850 mb, the temperature at 850 mb must be significantly colder than the underlying surface (maybe on the order of 10°C or greater)

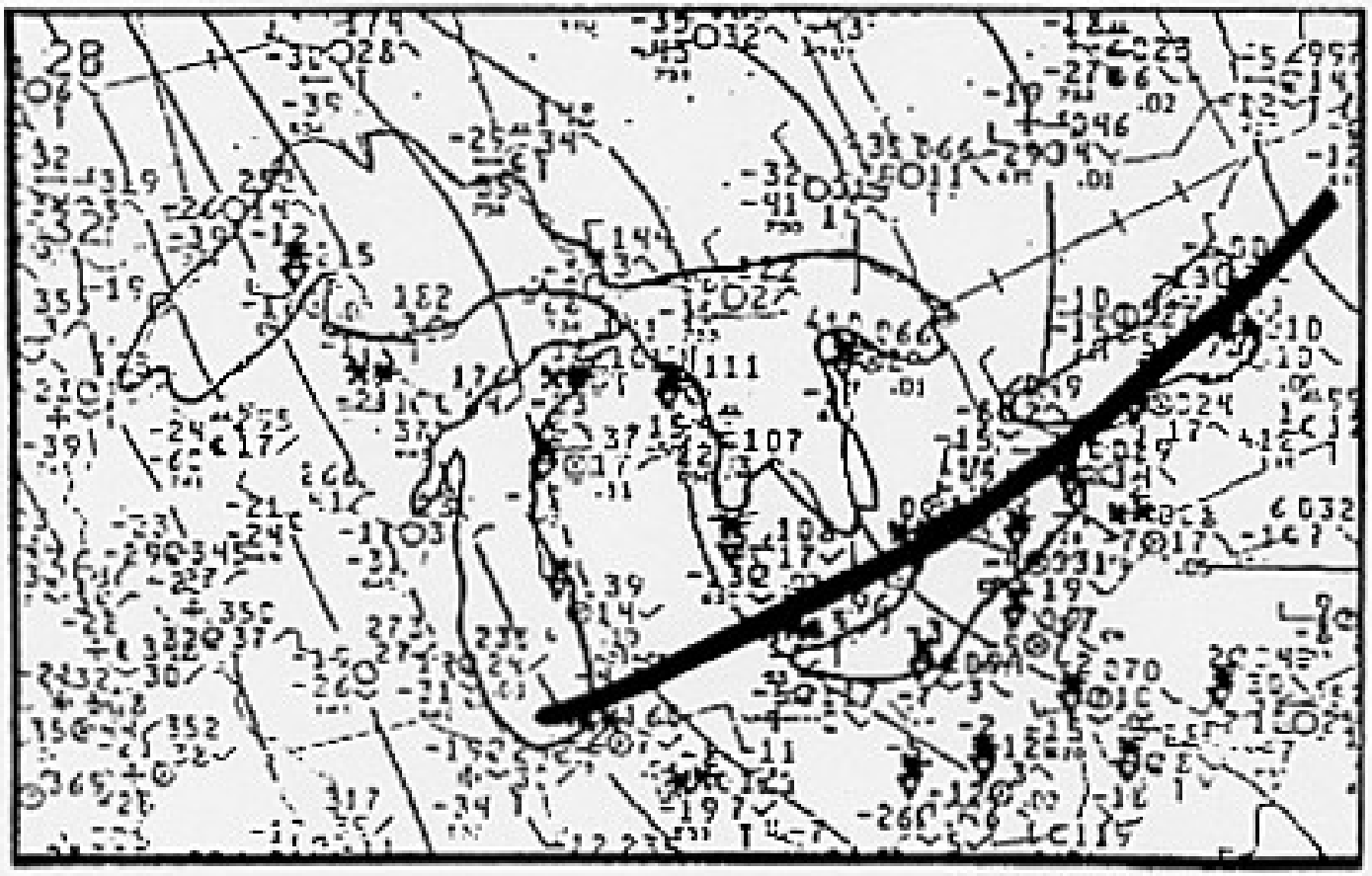
Troughs

- Strong cyclonic turning exists at low levels, enhancing convergence and lifting there.
- Common in strong CAA, behind strong cold fronts
- Caused by low-level heating of advancing cold air

Troughs

- Results from upward transfer of heat (and moisture, if over water) from surface into cold air
  - Warming produces surface pressure falls or less rise
  - Axis of strongest low-level heating will develop into trough

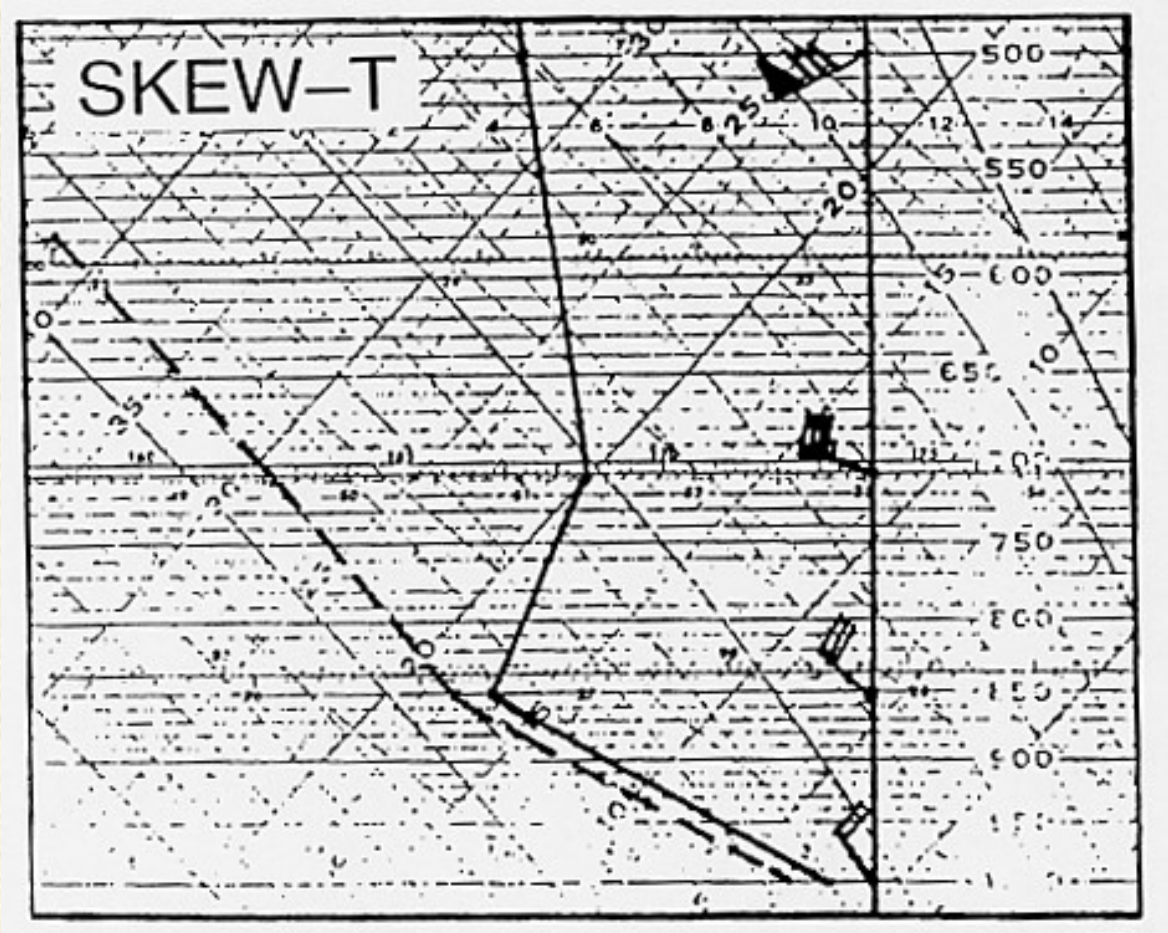
Typical Trough over the Great Lakes During a Cold Outbreak



Troughs

- Atmosphere destabilizes due to warming from below
  - Convective clouds and scattered precipitation will result
  - Precipitation most likely occurs near trough axis because of low-level convergence

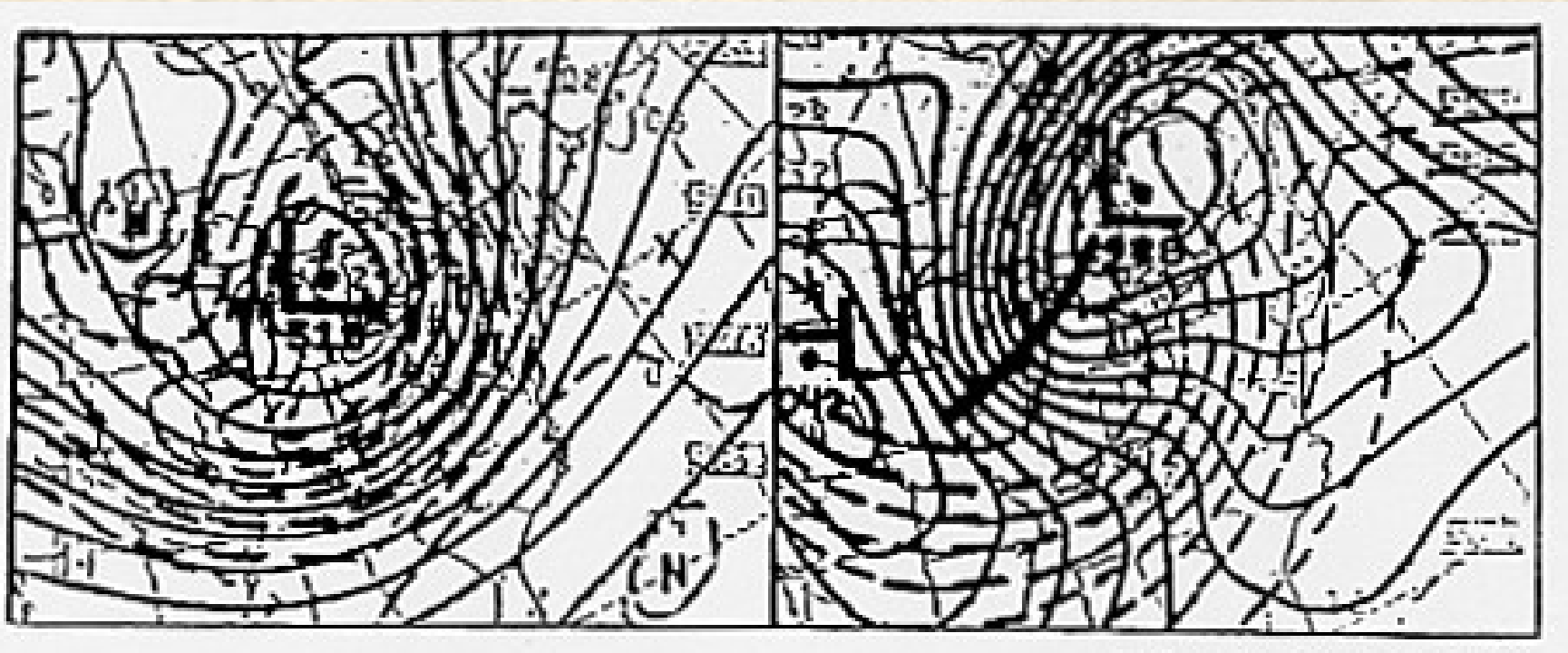
Skew-T of Post Frontal Trough



Troughs

- Common behind deep baroclinic lows
  - Frequently seen over Great Lakes in winter
    - Unfrozen lake can be 25 C° warmer than air at 850 mb
    - Baroclinic low departing Great Lakes often trails strong surface trough back into Lakes region
  - Similar situation occurs along east coast of US
  - Fairly common during autumn in central US

Post Frontal Trough



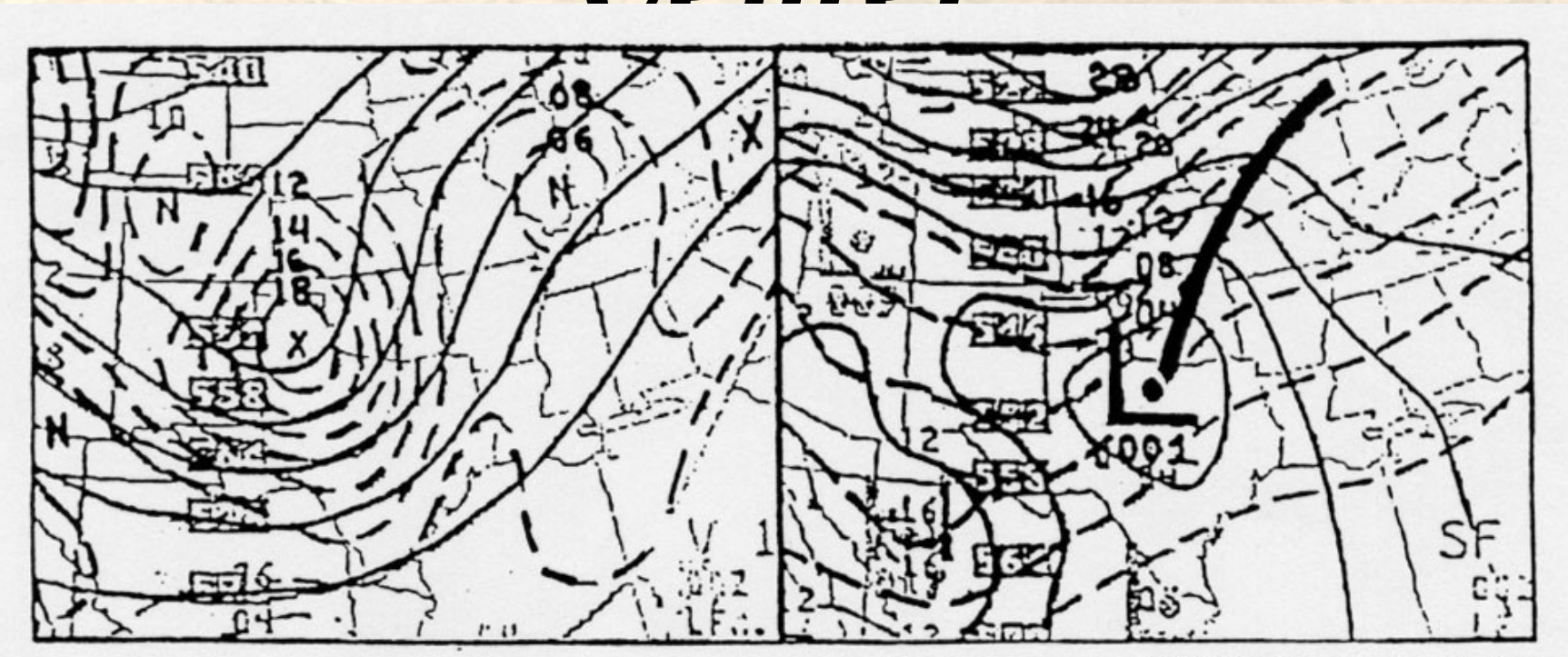
Troughs

- **Upper-level forced trough**
  - May be either baroclinic or equivalent barotropic
  - Must stack from upper-level feature supporting it
    - Baroclinic troughs tilt with height
      - Stack toward colder air (i.e., lower thickness)
      - Short-wave troughs at 700 mb and 500 mb will stack from the 850-mb trough progressively toward lower 1000-500 mb thickness

Troughs

- Equivalent barotropic troughs show little or no tilt
  - Primarily reflection of upper-level flow pattern
  - Winds turn cyclonically across trough axis
  - Common behind surface fronts
  - Not necessarily under PFJ
  - Weather similar to COW trough Common in cold air west of deep baroclinic low

Inverted Trough North of a Baroclinic Low Center



Troughs

- **Baroclinic Inverted troughs**
  - Strongest at the surface and weakens with height
  - Winds turn cyclonically across trough
  - Typically occurs north of baroclinic low
  - It is not necessarily beneath PFJ

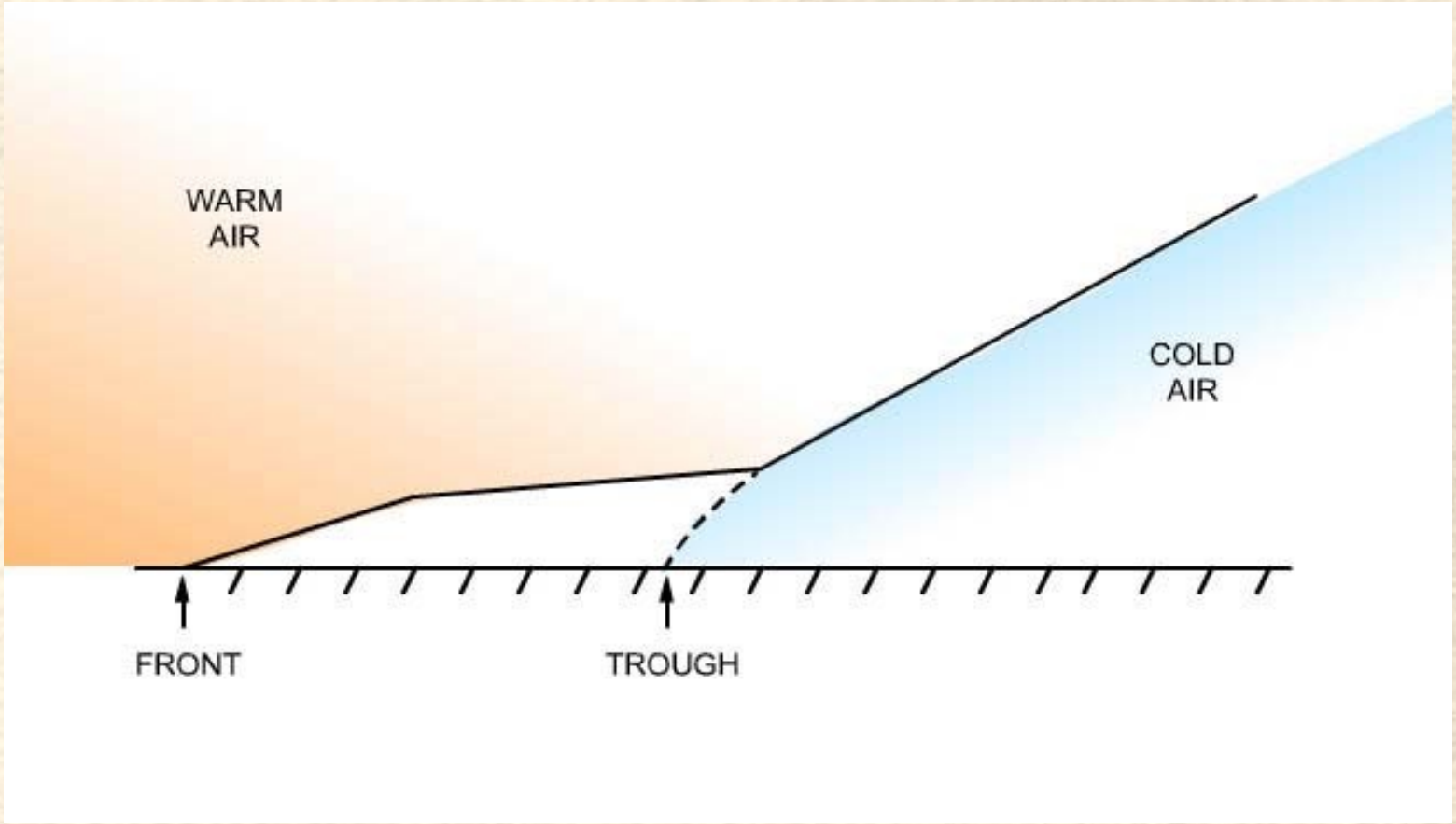
Troughs

- Causes
  - Change in slope of warm frontal surface
  - Forms where slope becomes steeper
  - Many times, this change in frontal slope is influenced by the density and static stability of the colder air mass near the surface.

Troughs

- If a vigorous short-wave trough moves well north of the polar front and across a region where shallow dense cold air is widespread and well entrenched over a region, the surface low may actually be located down along the polar front while an inverted trough extends northward through the colder air, reflecting the upper-level divergence induced over the colder air by the upper-level trough and jet stream.

Warm Frontal Slope and the Inverted Trough



Troughs

- Widespread moderate or heavy precipitation typically occurs due to enhanced lifting from warm advection aloft and jet-induced divergence associated with an upper-level trough.
- Common with baroclinic lows, in central US, during winter.
  - For example: An inverted trough often occurs in Texas as a short-wave trough aloft traverses shallow dense cA air there. Polar front is located well south or southeast over Mexico or the Gulf of Mexico.

Classification of Systems

- **Can change from one to another**
  - System becoming more equivalent barotropic will become more vertically stacked
  - System becoming more baroclinic will become less vertically stacked

Classification of Systems

- **When classifying systems**
  - Classic systems will not always look same
  - Use the classification that BEST describes system.
  - Be flexible and try and justify your classifications based on overall dynamic structure of the system.

- APPLICATION: Assign Review Exercise 1
- EVALUATION: Administer and evaluate Appraisal 205a. Written test at the end of the unit.